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ABSTRACT

This work is concerned with the analysis of industrial energy use for the purposes of reducing that use to a minimum within the constraints imposed by the existing plant. The work is divided into two parts.

Firstly, a general analysis of the energy used in an industrial plant is made for the year 1986. Based on monthly records of energy consumption and environmental parameters, it is primarily intended to heighten management awareness of energy flows and the relative contributions from each energy type towards the total annual consumption and cost. It is performed using a suite of interactive linked computer programs and the data is reduced to a graphical form for presentation in a report. The analysis is a first approximation, assuming steady state conditions with many parameters time and space averaged, but is justified by the findings that monetary savings approaching 5% of the annual energy bill could be made with changes to operational procedures alone.

As a result of this work, it was revealed that the boiler-house supplying the majority of the plant with high pressure hot water for process and space heating requirements used more than half of the total annual energy requirements and that potential energy savings were likely.

Secondly, a detailed analysis of the energy used by the boiler-house is carried out. A real time monitoring and targeting system which records and displays boiler, environmental and plant parameters is developed and installed. Data gathered over a period of six months enables (i) specific cases of energy wastage resulting from operational procedures to be identified and (ii) trends of performance indicating poor energy efficiency to be traced. The system developed may be used to provide the information necessary to enable improved control.

A general result which may be inferred from this work would be that the combined approaches of a top-down general analysis and a bottom-up detailed analysis of energy use can provide significant opportunities for energy conservation resulting solely from the improved operation of large energy consuming plant.

The work was performed at a major manufacturing plant in the U.K. with an annual energy consumption of the order of 600 gigawatt-hours and an annual energy bill of the order of £10 million.

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w	watts
Kw	Kilowatts
Mw	Megawatts
Gw	Gigawatts
Tw	Terrawatts
Kwh	Kilowatt-hour
Mwh	Megawatt-hour
t.c.e	one tonne of coal equivalent
m.t.c.e	one million tonnes coal equivalent
g.t.c.e	one thousand million tonnes coal equivalent
t.o.e	one tonne oil equivalent
m.t.o.e	one milion tonnes oil equivalent
g.t.o.e	one thousand million tonnes oil equivalent
bbl.	barrel of oil
mbd	million barrels of oil per day
gigatherms	one thousand million therms
gigatonnes	one thousand million tonnes
U-value	k/d where; k = thermal conductivity and d = thickness of material. in watts per square metre per C

a/c	air changes per hour
m.	metres
sq.m.	square metres
m/s	metres per second
V	volts
mV	millivolts
A	amps
mA	milliamps

CHAPTER 1

INTRODUCTION

1.1 World Energy Consumption.

The direct use of energy by man had by 1985 reached a continuous average rate of approximately 11.5 TW (terawatts) (Holdren, 1987) which is equivalent to an annual consumption of approximately 13.5 thousand m.t.c.e. (million tons of coal equivalent) or 2.4 kW per person for a world population of over 4.8 billion. Approximately 90% of this total figure is from commercial (industrial) energy forms and 10% from traditional energy forms. The growth in commercial energy demand from 1950 to 1982 is shown in fig.1.1 (British Petroleum, 1982) and the total primary commercial energy demand is disaggregated by energy source for 1982 in fig.1.2 (Dunn, 1986; Inst.En., 1986). It can be seen that fossil fuels contribute approximately 90% towards commercial energy demand with nuclear and hydro-power contributing the remainder. It is difficult to quantify the contribution towards total world demand from traditional forms such as firewood and vegetable wastes as statistics are not available as they are for commercial energy forms. A figure of 10% has been taken above but it may be as high as 15%.

One estimate of ultimately recoverable world non-renewable energy resources is almost 6000 gigatonnes of coal equivalent (Dunn, 1986). The relative contribution of each resource is shown in fig.1.3 with coal alone contributing three quarters of the total resources and uranium less than 2% (based on light water reactor technology). Total coal resources are approximately double those indicated but accessibility to all of them is limited for technical reasons. At current consumption rates (12.2 thousand m.t.c.e per year for commercial energy), these commercial resources would last approximately 500 years whilst an annual increase in the rate of consumption of 5% would reduce their lifetime to less than 70 years.

Since 1950, the increased demands of world energy consumption have been met mainly by oil and gas, with coal usage increasing relatively slowly. This has been due to the convenience of these two fuels and their very low cost, pre 1973. It is expected that whilst their combined contribution towards global demand will increase in absolute terms into the next century, their relative contribution will diminish as the coal and nuclear contributions increase (see section 1.4). The 1973 plateau in world energy consumption shown in fig.1.1 is a result of the oil crisis of that year which followed an OPEC price increase. The effect of this crisis was to reduce the annual rate of increase in oil consumption from 7% (1945-73) to 1.25% (1973-80) (Dunn,1986). This abrupt levelling of world energy consumption in 1973, due solely to an oil price rise from $3/bbl (per barrel) to $9/bbl clearly demonstrates the strong dependency of world energy consumption on the price of oil. A further increase in the price of oil to $18/bbl in 1978-9 following the Iran-Iraq war accumulated with previous increases to result in an order of magnitude rise in the price of oil in a decade. In 1985 oil prices had risen to $30/bbl and unrestrained oil production policies, including those of the U.K., had created an over-production of world oil which reduced the demand for OPEC oil to less than 20 mbd (million barrels per day) (Energy Information Centre, 1987). In order to re-establish their market share, OPEC forced a price drop to less than $10/bbl in 1986. As a result of this precipitous price fall and a continuing surplus of world oil, the current price of oil is relatively low at around $15/bbl. This low oil cost coupled with recovery from the recession of the early 1980's has caused the recent trend in world energy consumption to move upwards.

1.2 U.K. Energy Consumption.

The trends in U.K. energy consumption of the main primary fuels over the recent 25 year period are shown, on a logarithmic scale, in fig.1.4 (Tempest, 1983, DOE, 1985 and DOE, 1987(a)). The upward trend in total energy consumption prior to the oil crisis of 1973 is clearly evident and this is due mainly to the rise in petroleum and natural gas consumption during this period. The effects of the oil price rises of 1973 and 1979 have been to produce marked and immediate downturns in petroleum consumption, which have been reflected by corresponding reductions in the total consumption figure. The effects of the economic recession of the early 1980's augmented those of the 1979 oil price rise to hold total energy consumption relatively low until 1984. (Note: The trough in coal consumption and the associated peak in oil consumption results from the coal miners' strike of that year). The annual consumption figures since 1984 show an overall increase in total U.K. energy consumption with the 1987 figure, 85.2 gigatherms (provisional), (DOE, 1988) some 10% higher than that of 1984 - 77.4 gigatherms. This rising trend is in accord with that for world consumption.

The contributions from each primary fuel towards the total energy consumption, for 1986, are shown in fig.1.5 (DOE, 1987(a)). The fossil fuel contribution of 93% indicates the extent to which U.K. energy requirements exploit the finite reserve of non-renewable fuels, with the remaining 7% being supplied by nuclear power, hydro-power and imported electricity.

The breakdown of energy supplied to final users is shown in fig.1.6 (DOE, 1987(a)) where the three sectors; industry, transport and domestic consumers share, approximately equally, over 85% of the total energy supplied. The difference between the total primary fuel consumption (84.8 gigatherms or 335.2 mtce.) and the total energy supplied (57.9 gigatherms or 231.6 mtce.) is attributed to losses in conversion and distribution of the national energy supply infrastructure. These losses (26.9 gigatherms) amount to some 32% of the total primary fuel energy input and approximately 70% of these losses (18.7 gigatherms) results directly from the low efficiency of electricity generation which is approximately 30%. The flow of energy in the U.K. from the input as primary fuel to the output supplied to final users is shown in fig.1.7 (DOE, 1987(b)).

1.3 U.K. Industrial Energy Consumption.

The energy supplied to industry (excluding iron and steel) for each energy type is shown in fig.1.8. There are significant contributions from all inputs except coke. Natural gas is now the favoured fuel in industry, where it is considered a premium fuel by virtue of its desirable qualities from a consumer's standpoint: it is easily transported by pipeline; unlike coal or oil, it requires no storage facilities and it burns easily and relatively cleanly. Although natural gas might appear, from fig 1.8, to be the predominant industrial primary fuel, this is not the case. If conversion and distribution losses are evaluated for each energy input, it is found that the primary fuel required to generate 2.5 gigatherms of electricity at a mean efficiency of 29.9% amounts to 8.4 (i.e. 5.8 + 2.6) gigatherms which is considerably larger (41.5%) than the primary fuel industrial inputs for either gas (26.8%) or petroleum (20.7%). The main primary fuel for electricity generation is coal (69% of the total) and hence the electricity supplied to industry is produced at the expense of some 5.8 gigatherms of coal. If this indirect contribution from coal is added to the direct coal and coke input then the total primary energy industrial input from coal totals 8.04 gigatherms. This is significantly greater than the primary fuel inputs from natural gas or petroleum and accounts for almost 40% of the total industrial primary fuel input. This is shown in fig.1.9. If the iron and steel industry is included which is a large coke consumer, then the primary fuel input from coal rises to 11.26 gigatherms which is nearly 46% of the total input (24.6 gigatherms). Hence, coal's contribution, directly and via generated electricity, approaches one half of the total industrial energy demand in the U.K..

1.4 Future Energy Trends.

Estimates of future world energy requirements are uncertain. Predicted world energy requirements up to the year 2000 differ by a factor of five (O'Keefe, 1987) and uncertainty increases to a factor of 120 up to the year 2087 when upper estimates exceed available resources. Such divergence is not surprising because of the multiplicity of factors which affect consumption and the assumptions made for these factors in the various future energy scenarios. For example, Johansson and Williams (Johansson, 1987), assuming radical changes in existing policies with major shifts towards end-use energy strategies, predict a global demand in 2020 of 11.2 TW (equivalent), which is less than the current (1988) figure. Given the extent to which long-term policies relating to energy use have changed in the past 15 years, since the 1973 oil crisis, such a prediction might be considered rather optimistic.

Most well known analyses of future global energy requirements put global energy consumption 40 to 50 years from now as 2 to 4 times the 1980 level. Projections for the year 2000 and beyond are shown in fig.1.10 (Johansson, 1987) and two of these projections, namely WEC (World Energy Conference), (Frisch, 1983) and IIASA (International Institute for Advanced Systems Analysis), (Hafele, 1981) are disaggregated by energy source and compared with the actual 1980 consumption in fig.1.11. For both projections, the scenarios depicted are averages of their low and high growth scenarios where the primary energy associated with nuclear power is taken as thermal energy released in the fission process.

The increased oil demand associated with projected energy requirements would make the current oil glut short lived and as Chandran (Chandran, 1986) has pointed out, it would be unfortunate if this glut resulted in a sense of euphoria. Even a modest growth in world oil demand would would make a shift of oil power, in recent years temporarily relinquished, back to OPEC (Oil Producing Economic Community) inevitable, as more than one half of the world's remaining oil resources, outside of the centrally planned economies, lie in the Middle East / North African region. As mentioned above, the current oil price is low and forecasts indicate (Chase, 1986) that whilst they remain low, world demand will rise as it did in the 1960's. Furthermore, with a significant fraction of all exploration and production drilling temporarily suspended, due to the low oil price, it is forecast that another oil crisis will occur before 1991 (Chase, 1986).

It is expected that economic activity in industrialised countries will be less energy intensive in future because of a shift away from basic goods production towards the production of increasingly refined and complex goods and services. In the USA, for example, a transition to a post-industrial economy continues where the industrial base is being reshaped. Of the three industrial sectors: mining, agriculture and construction (MAC); basic materials processing (BMP e.g. petroleum, metals, cement, paper) and other manufacturing (OMFG) , the basic materials processing sector, which dominates industrial energy use, accounted for 25% of the industrial output, in dollars, but 73% of industrial energy use (Williams, 1987). In the period 1973 to 1984, the OMFG sector (which involves the fabrication and finishing of basic materials) grew roughly in line with GNP at 25% per year whilst the BMP sector grew at a mean rate of only 0.5% per year (Ross, 1987). Such a decline in the BMP sector implies increased reliance on imports.

In developing countries, however in contrast, the use of materials is growing more rapidly and, in general, industrialisation programmes demand increasing industrial energy consumption rates. Hence in countries such as China, Korea and Brazil, industrial energy use will increase rapidly whilst in countries such as USA, Europe and Japan, it will increase less rapidly or level off.

A fundamental driving force behind the problem of increasing energy demand is population growth and it is expected that the fifty year period, 1980 to 2030, will coincide with the steepest increase ever in global population (Keyfitz, 1977). The population in 2030 will have doubled from 4 billion in 1975 to some 8 billion. It is anticipated that this growth will cause a unique energy problem.

1.5 Environmental Effects of Energy Use.

In the process of energy conversion, 50 - 60% of the primary energy is dissipated directly into the environment by heating water and gases and in the processes of energy transmission and consumption most of the remainder is eventually degraded to heat and is dissipated. On the basis of estimates by Yu (Yu, 1981), current global energy usage of 13.5 thousand m.t.c.e involves more than 50 gigatonnes of atmospheric oxygen with the release of about 25 gigatonnes of carbon dioxide. The increase in atmospheric carbon dioxide, resulting mainly from fossil fuel combustion, since the middle of the last century has been of the order of 20% i.e. from 2200 gigatonnes to 2700 gigatonnes (1985). It is predicted (Holdren, 1987), that with a steady growth in fossil fuel consumption of 2% per year, atmospheric carbon dioxide concentrations will be doubled by 2050. Computer predictions, supported by paleoclimatological data indicate that a doubling of atmospheric carbon dioxide would produce an increase of between 2 and 3 deg.C in the mean global temperature (space and time averaged) (Clark, 1982).

Furthermore the burning of fossil fuels results in the emission of particulates, hydrocarbons, nitrogen and sulphur oxides and heavy metals (National Research Council, 1981, United Nations, 1984 and Seiler, 1980). In several cases, the global flow of these pollutants resulting from energy conversion is of the same order of magnitude as estimated, pre-industrial natural flows and the mobilisation of lead resulting from fossil fuel combustion is an order of magnitude greater (National Academy of Sciences, 1980) than pre-industrial natural flows (260 kilotonnes per year cf. 26 kilotonnes per year). Princiotta (Princiotta, 1988) has surveyed in detail the prospects for coal in the USA. He concluded that whilst the consumption of coal was bound to increase to meet future energy demands for the country, the sulphur and nitrogen oxides as well as the particulates could be kept within acceptable bounds. However, the increase of atmospheric carbon dioxide with its associated global warming presents a more intractable problem. Notwithstanding a major technological breakthrough, for example the commercialisation of nuclear fusion or solar electric generation, the best that can be hoped for is to moderate emissions of carbon dioxide from the combustion of coal and other fossil fuels through the conservation of energy.

Nuclear power is considered a cleaner alternative to fossil fuel derived power assuming accident-free operation. The air required to dilute emissions from nuclear plants is thousands of times less than that required for fossil fuel plants on a per unit energy produced basis (Yu, 1984) and whilst the radioactive wastes from nuclear plants are far more toxic than the wastes from fossil fuel plants, their volume (per unit energy) is of the order of 10 million times smaller. However, the nuclear catastrophe at Chernobyl, USSR in 1986 demonstrated the effects that a nuclear accident may have. It is estimated that only 3.5% of the total radioactivity accumulated in the reactor was released into the environment (Yu, 1987), yet the effects of this relatively small release produced increased radiation levels in vegetation, livestock and humans in the U.K..

1.6 The Energy Predicament.

The problems associated with increasing world energy demand are now accepted within the scientific community as real and of major global significance. They result mainly from the ever increasing rate of fossil fuel and biomass depletion and the widespread effects of consumption of these fuels on the global environment. It is clear that the real cost of energy production including the human and environmental costs is significantly greater than the monetary costs. Continuing adherence to simplistic accounting procedures and policies which do not internalise the environmental costs of energy consumption will exacerbate the problems which have been evident for some 18 years (SCEP, 1970). Furthermore, it is evident that further increases in global energy consumption as a result of population growth and an increasing per capita energy consumption will be costlier, economically and environmentally, than those hitherto. This is so for several reasons (Holdren, 1986): further growth in energy demand will be satisfied by resources of a lower quality or of a marginal nature; new energy sources such as fusion and photovoltaics will require such large capital expenditure that the delivered cost will be high despite the low or zero cost of fuel input; the capacity of biogeophysical systems to absorb the deleterious effects of energy consumption has been substantially reduced; the requirement to reduce the environmental impact of supplied energy through improved technologies; and a significant fraction of predicted energy growth will occur in developing countries where environmental costs will, at best, be of secondary importance.

1.7 Non Fossil Fuel Energy Sources.

Between 1960 and 1972, world energy demand rose at over 4% per annum and this growth was rapidly curtailed with the advent of the oil crisis in 1973. Proposed solutions to the envisaged problems of energy supply and demand included energy conservation, fuel substitution, alternative energy sources and nuclear power. Since then, there has been a slower than anticipated growth in nuclear power, a five fold increase in the decade following 1973, (Fells, 1987(a)) with a predicted contribution from nuclear electricity of about 10% towards world energy supply by the year 2000 (Fells, 1987(b)).

One result of the 1973 crisis was to promote a growth of interest in the renewable energy technologies such as wind, waves, solar and biomass. Some of these technologies had been well established in principle and to a limited extent in practise for many years. Solar collectors (Brinkworth, 1972) had attracted considerable research and development interest in the 1950's, particularly in the USA

(Daniels, 1954, Conf. Use of Solar Energy, 1955 and Proc. World Symposium, 1955) and had operated successfully in the southern USA, Japan, Australia and Israel. The first cost of solar collectors together with the low temperatures of collection attainable without the use of concentrating devices or selective surfaces, mitigates against their widespread use in areas where a cheap conventional energy supply is available. Attention now in the field of solar energy utilisation, especially in the U.K., has turned towards passive solar design (Norton, 1987) where large additional capital expenditure is not required.

Wind energy research had been carried out in the 1940's (Thomas, 1945 and Golding, 1949) and resulted in the successful development of small aerogenerators- typically 200 watts- which are still manufactured today. The development of large machines in that era were not so successful however - the Smith-Putnam turbine in Vermont was decommissioned after one of its two blades broke off in strong winds. Current U.K. interest in large wind machines is strong, as certain sites in the U.K. (e.g. the North-West and Scottish Islands) offer considerable potential for aerogeneration, and a number of groups are currently installing large machines. The largest of these is The North of Scotland Hydro-Electric Board's 3 MW machine which is currently (1988) being commissioned on the island of Orkney . The CEGB (Central Electricity Generating Board) recently announced (1988) increased spending of 30 million pounds on wind research as they estimate that windpower could eventually supply 20 - 40% of the U.K.'s electricity requirements with 1000 MW of capacity being installed by the end of the century. In California, wind energy supplies 3% of the state's electricity requirements with 14,000 wind machines currently installed with a rated capacity of 1500 MW, generating 1.2 billion Kwhr of electrical energy annually (Inst. Mech. Eng., 1988).

The theoretical potential of renewable sources of energy exceeds present needs by a factor of 150 (Davis, 1987) and the necessary technology is currently available. Generally however, such sources are costly, of low intensity, variable and require energy storage. Unfortunately, they have not fulfilled the hopes held for them some 15 years ago, partly because of their intrinsic limitations and partly because of the low cost of conventional energy sources. It is felt that the potential application of renewable energy sources must be viewed within the context of the total energy supply and demand problem and it would be ludicrous to proceed with large scale applications before ensuring that the efficiency of energy end use is maximised. An example, in this work, is that of electricity consumption for the plant surveyed. It is noted that with improved energy management, savings in electricity consumption exceeding 3 MW (i.e. the rated output of the new Orkney wind turbine - the largest in the world) could be realised.

It is estimated that renewable energy resources might contribute approximately 5% of Europe's energy needs by the year 2000.

1.8 Energy Policies.

It is apparent from fig 1.11 that there will be continued dependence on fossil fuels both as primary and secondary energy sources for several decades to come. It is evident that improving the efficiency of energy usage supplied by these fuels or other sources is of paramount importance.

In industrialised countries, energy conservation programmes were instituted as a result of the 1973 crisis and the effects of these programmes are discussed by Carter (Carter, 1985). Japan has achieved considerable success, a growth in GDP (gross domestic product) of 39% between 1973 and 1982, with only a 1% increase in energy usage and a reduction of 34% in the industrial energy use-production ratio. In contrast, the U.K. has reduced its energy/GDP ratio by 20% but this is partially due to the increase in GDP resulting from the production of North Sea oil.

Historically, the U.K. has been strong in energy efficiency. It is estimated that in 1913 the efficiency of coal utilisation was only 13% rising to 30% in 1947 and 50% in 1980. During and immediately after the Second World War considerable efforts were devoted to energy efficiency - conferences on the efficient use of energy were held, reference books were produced and fuel technology programmes were instituted. With the discovery of North Sea oil and gas and the great expectations for nuclear power, there was a decline of interest in energy efficiency. In the Fuel Policy document (HMSO, 1967) presented to Parliament, no reference was made to energy conservation. The 1973 crisis caused the Government to rethink their policy and several measures were proposed: a loan scheme for energy-saving investment in industry; energy saving schemes for buildings including a compulsory room temperature limit of 20 deg.C; a reduction in the maximum speeds of vehicles and a publicity scheme for conservation launched by the Department of Energy. In 1978, a Government Green Paper called for energy conservation efforts to reduce overall U.K. energy consumption by 20% by the year 2000. The Watt Committee (Watt, 1978 and Watt, 1979) proposed a figure of 30% - 10% by 'good housekeeping' and 20% by technological conservation. Despite such auspicious projections, energy reduction in the U.K., resulting from energy conservation measures is only about 3% in the last ten years (Fells, 1987(b)).

Unlike other countries, such as Japan and the USSR., the U.K. has no national energy policy (Probert,1987) and this is indicative of the general lack of concern for efficient energy utilisation which is apparent at all levels of organisation within the U.K.. In industry, commerce, government, local authorities and the domestic sector, energy is wasted in a most profligate way - the effects of Government actions have been small.

The current U.K. Government attitude is one of 'laissez-faire' whereby market forces are allowed to control energy growth and consumption. Whilst this simplistic approach is expedient in controlling many commodities, it is hardly appropriate for such a valuable resource as energy for two reasons. Firstly, if the cost of energy were a true cost which internalised the costs of resource depletion and environmental degradation, the approach taken would be valid but this is clearly not so. Secondly, implicit in this attitude is the belief that market forces governed by economics can control the effects of energy consumption governed by the natural sciences - a fundamental error. The results of such short-sighted policies are exemplified by the case of acid rain. Despite the disastrous effects which have already been caused to lakes and forests, mainly in Scandinavia, by gaseous emissions from fossil fuel burning plant, including contributions from plant in the U.K., U.K. governmental action to reduce such emissions remains hopelessly inadequate with the intention of reducing emissions from only 3 out of 40 fossil fuel power stations by the end of the century. Accordingly, in the U.K., all lakes south of Loch Ness are under threat (FOE, 1988). Such lethargy is a direct result of the conflict between that which is economically desirable and that which is environmentally desirable - 'laissez-faire' will always favour the former.

1.9 Future Needs.

With the depletion of North Sea reserves, the need to import energy in the near future, current attitudes towards energy use and the lack of a national long-term energy management plan, the U.K. energy future looks uncertain at best. It is evident that, owing to a lack of investment in both the public and private sectors, the U.K. will fall far short of the EEC target of a 20% improvement in energy efficiency by 1995. Recent research has shown (Tinson, 1988) that 20% of U.K. energy could be saved for an investment of about 8 billion pounds. An investment of one billion pounds per year for 8 years is needed to enable the EEC target to be met but this is more than ten times the current rate of investment in energy efficiency programmes in the U.K..

Energy conservation is the one technology which must coexist with existing or future energy conversion technologies. It should now be regarded as fundamental in managing finite resources or renewable ones from both a resource and environmental standpoint. Apart from improvements in energy conversion technologies, such as fluidised bed combustion and CHP (Combined Heating and Power), there is considerable scope for increasing the efficiency at which the energy is finally used. This is certainly true for space and process heating where experience shows (as in this work) that energy consumption often exceeds the minimum necessary. This often results from inadequate information on the minimum energy requirements for a process and/or the lack of control. As a result, there is now considerable interest in the monitoring and targeting of energy use which has the objective of providing adequate information for management and operating personnel such that the functional dependence of energy consumption on the relevant parameters may be better understood. Operating procedures may then be modified in order to conserve energy.

University departments have a potentially significant role to play in improving the efficiency of energy utilisation. They can provide the motivation and expertise which is often lacking in industry. Co-operative ventures with industry using a bottom-up approach towards specific energy utilisation problems could prove most beneficial. The work of postgraduate students which is often perceived as irrelevant (Tweed, 1987) could be applied in this direction.

1.10 Thesis Aim.

The aim of this thesis is to investigate a method of analysing industrial energy usage for the purposes of reducing that usage to a minimum.

Owing to the nature of the problems encountered in attempting to reduce the energy consumption of a building or plant, it is believed that the preferred approach is essentially empirical. Accordingly, this entire work is based on an analysis of the energy used by a large manufacturing plant in the U.K..

The aim of this work may be considered in several parts viz:

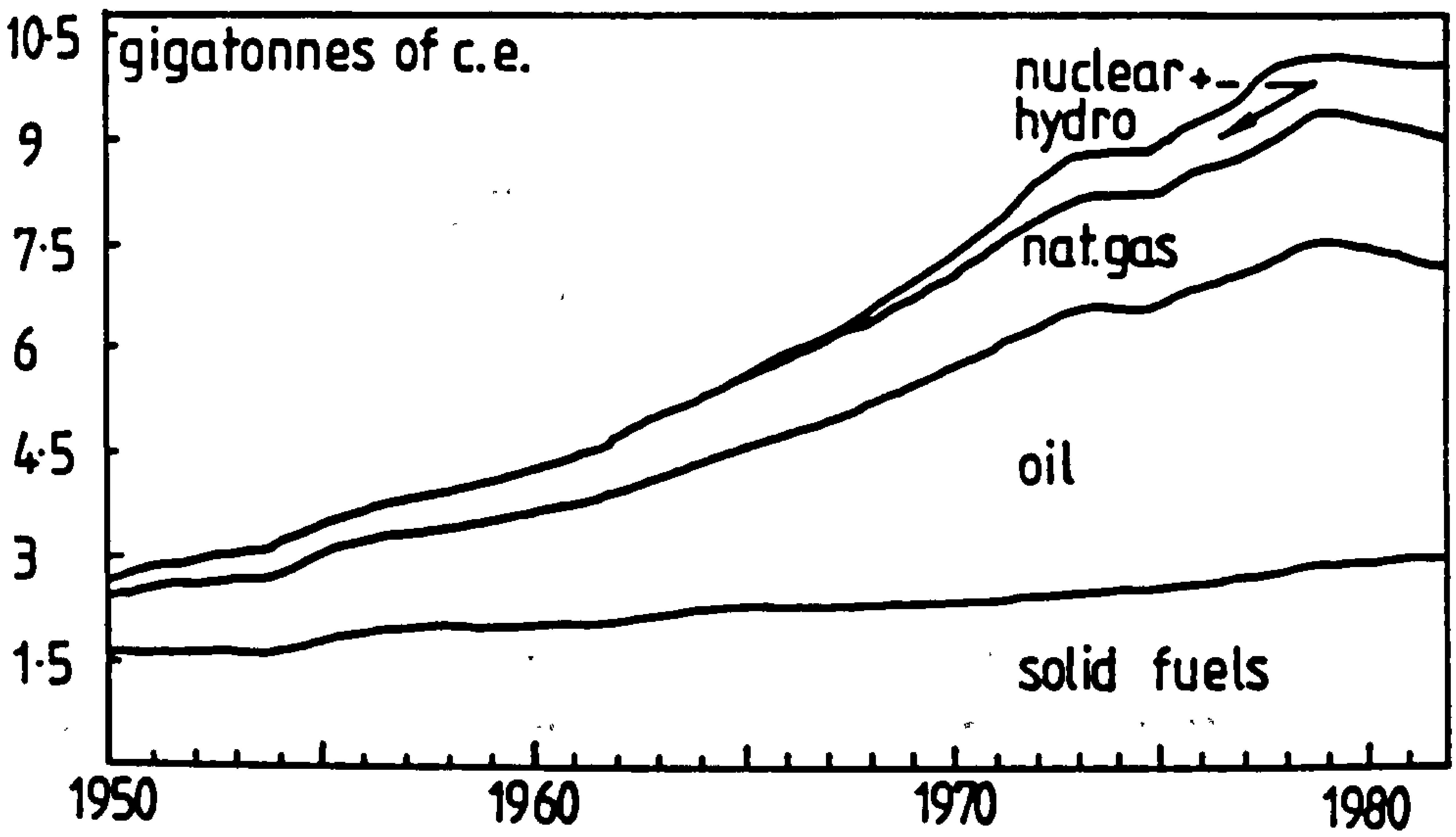
(1) To develop a suite of computer programs to produce tabular and graphical analyses of energy usage

data which may be directly incorporated into a general energy analysis report aimed at top management.

(2) To investigate the utility of this general energy analysis to indicate energy conservation opportunities.

(3) For a suitable conservation opportunity which may be apparent from (2), to develop a system, to monitor in real-time, the energy consumption and other relevant parameters, such that methods of reducing energy usage may be identified. The results of any such detailed analysis would be aimed at the plant management level.

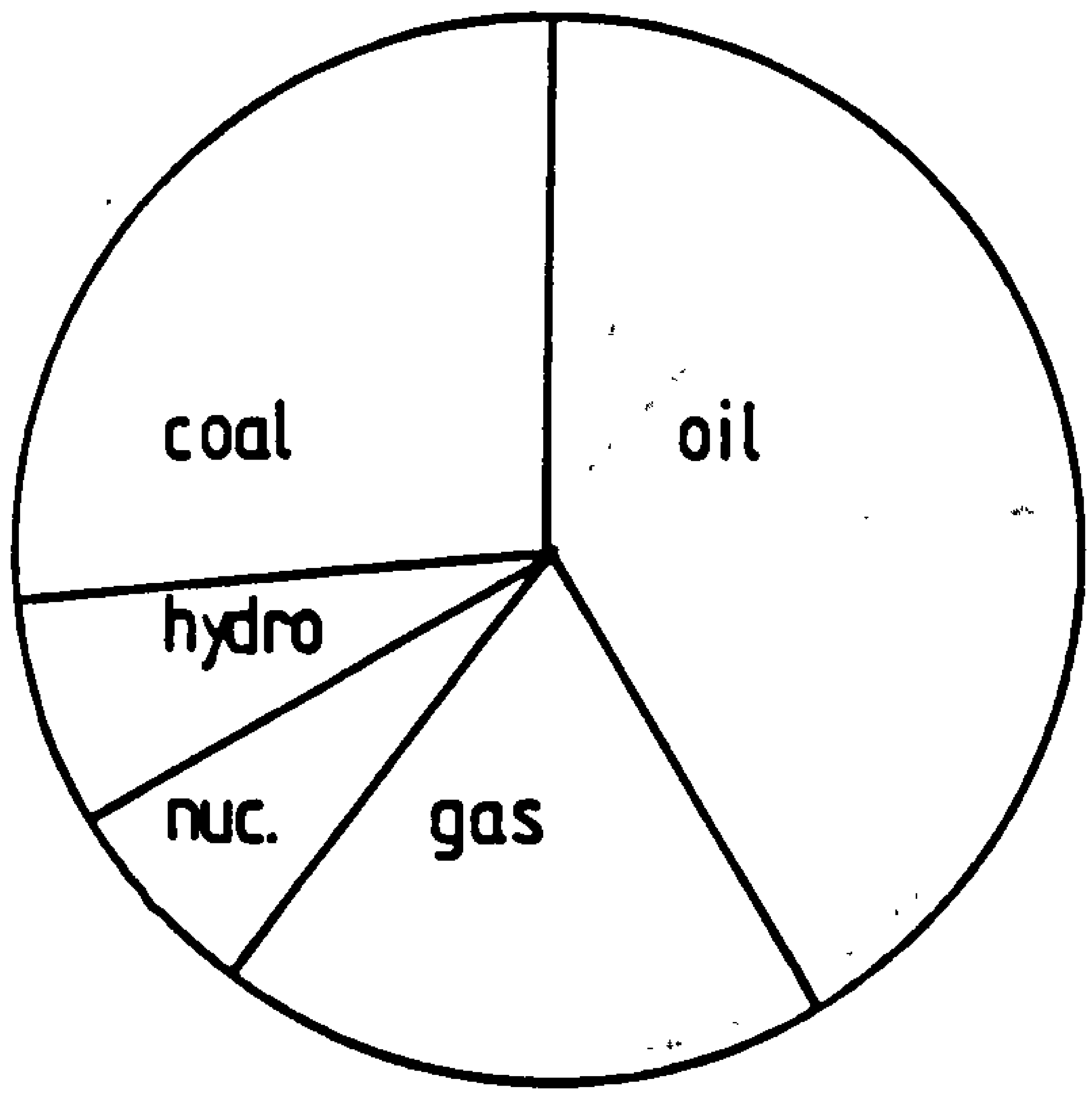
Whilst based on a specific case study, it is believed that, should useful observations be forthcoming, then the approach may be usefully employed in other cases.



World commercial energy demand

(British Petroleum, 1982)

Fig.1.1

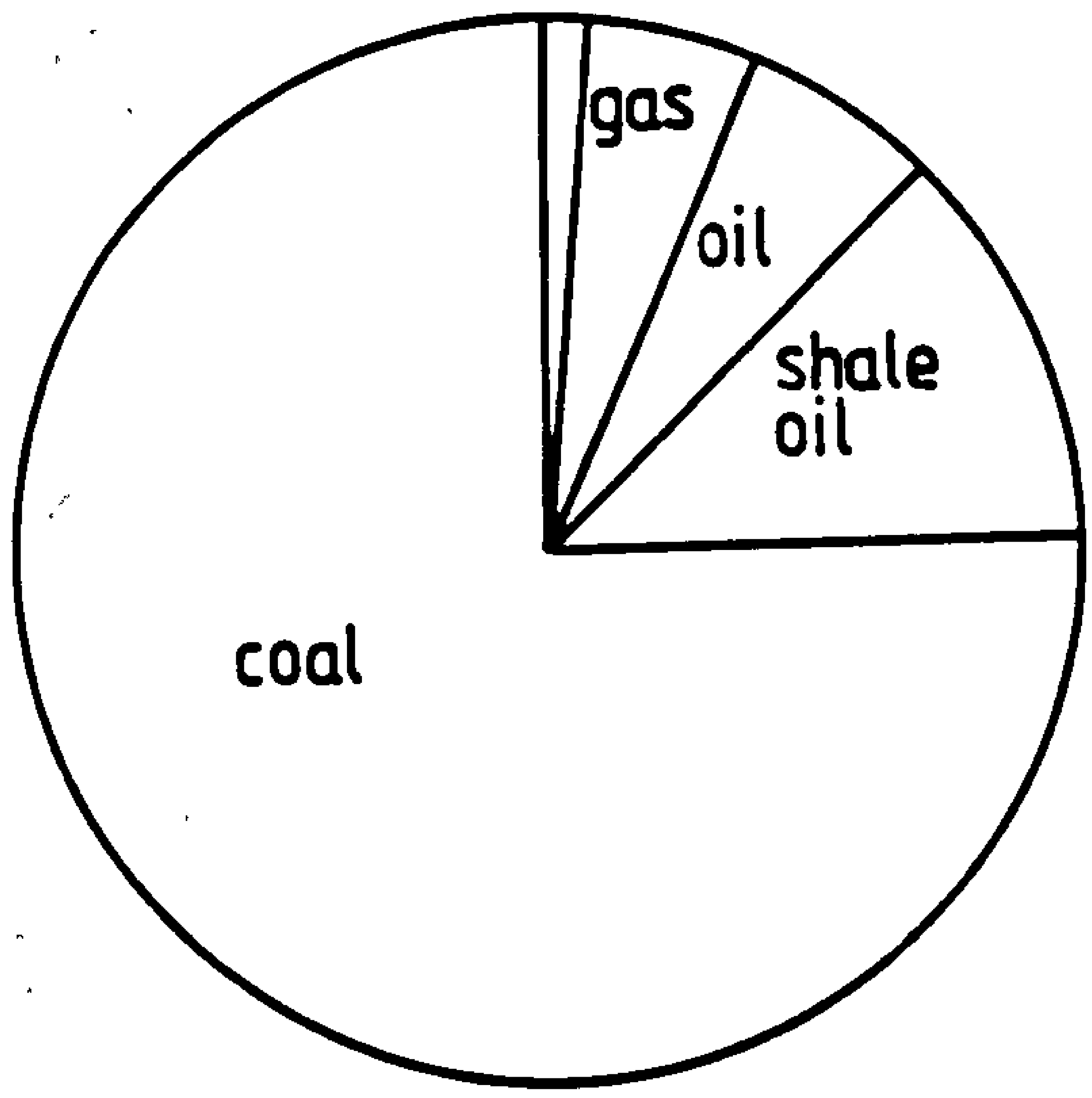


primary fuel	gtce	%
oil	4·53	41·7
gas	2·03	18·7
coal	3·18	29·3
hydro	0·74	6·8
nuc.	0·36	3·3
total	10·86	100

World primary commercial energy demand 1982

(Dunn, 1986 , Inst. En., 1986)

Fig.1.2

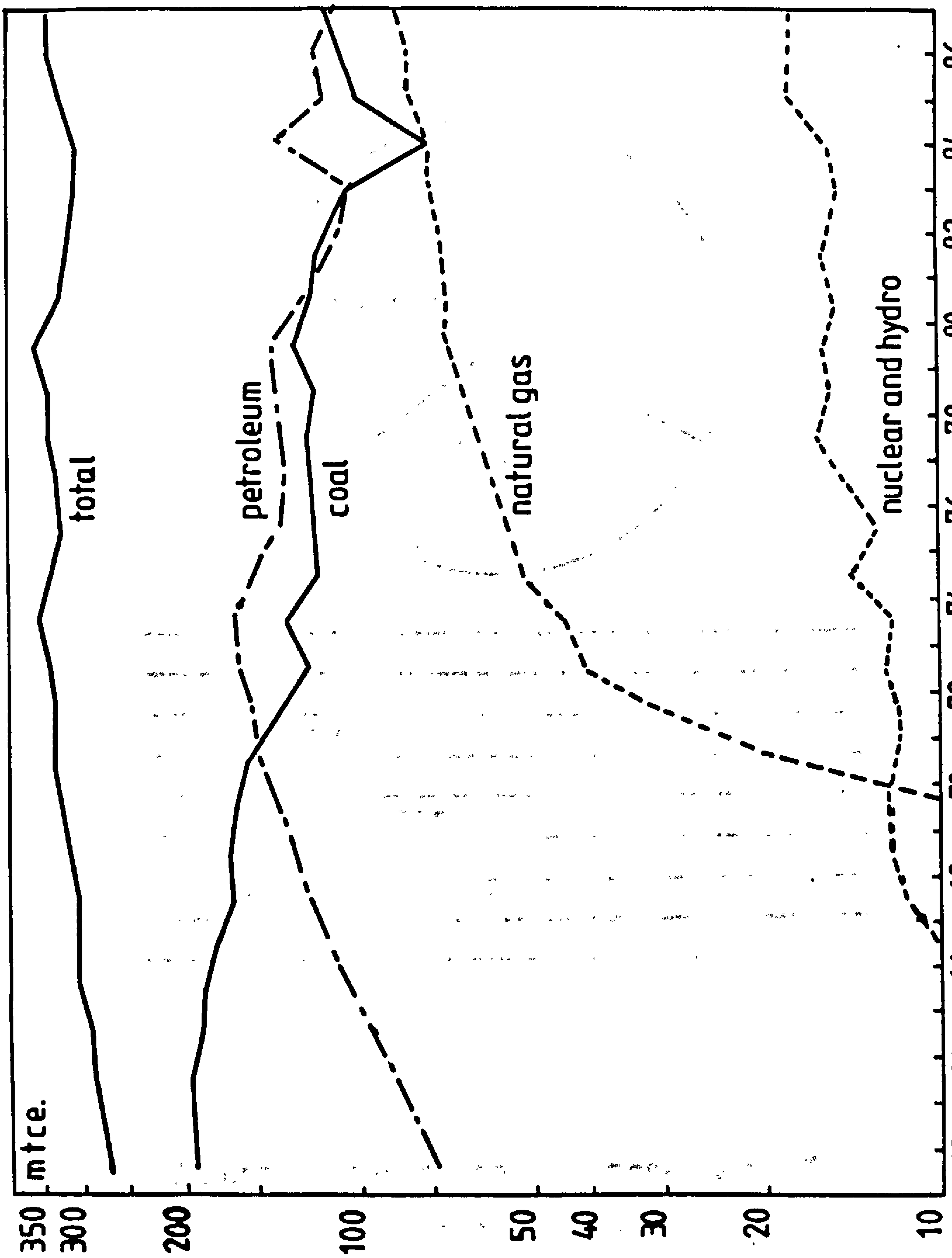


energy resource	gtce	%
oil	350	6
nat. gas	310	5·4
coal	4400	75
shale oil	730	12·5
uranium	70	1·2
total	5860	100

Ultimately recoverable world non-renewable energy resources.

(Dunn, 1986)

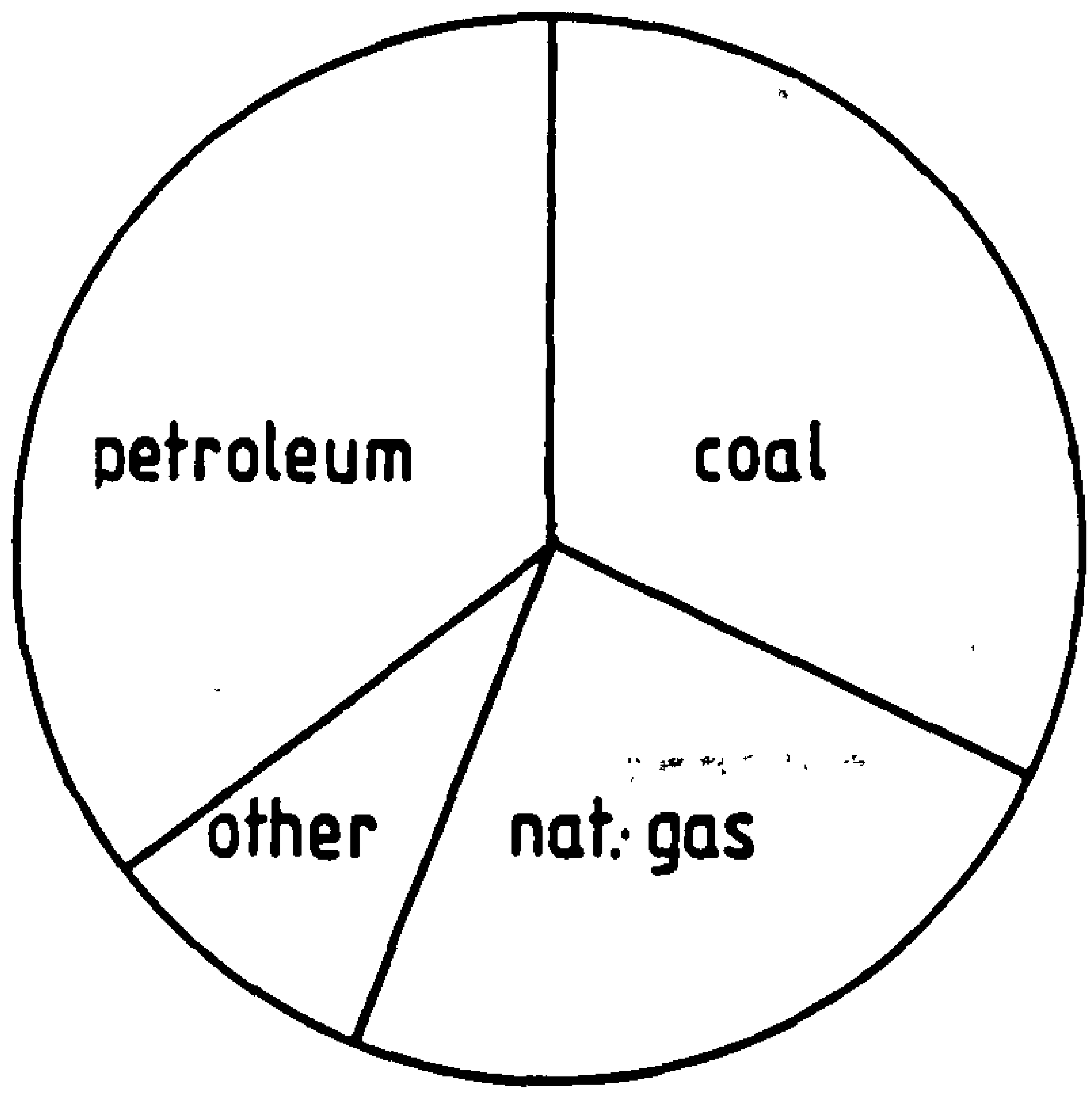
Fig.1.3



UK. consumption of primary fuels for energy use.

(Tempest, 1983 et al.)

Fig.1.4

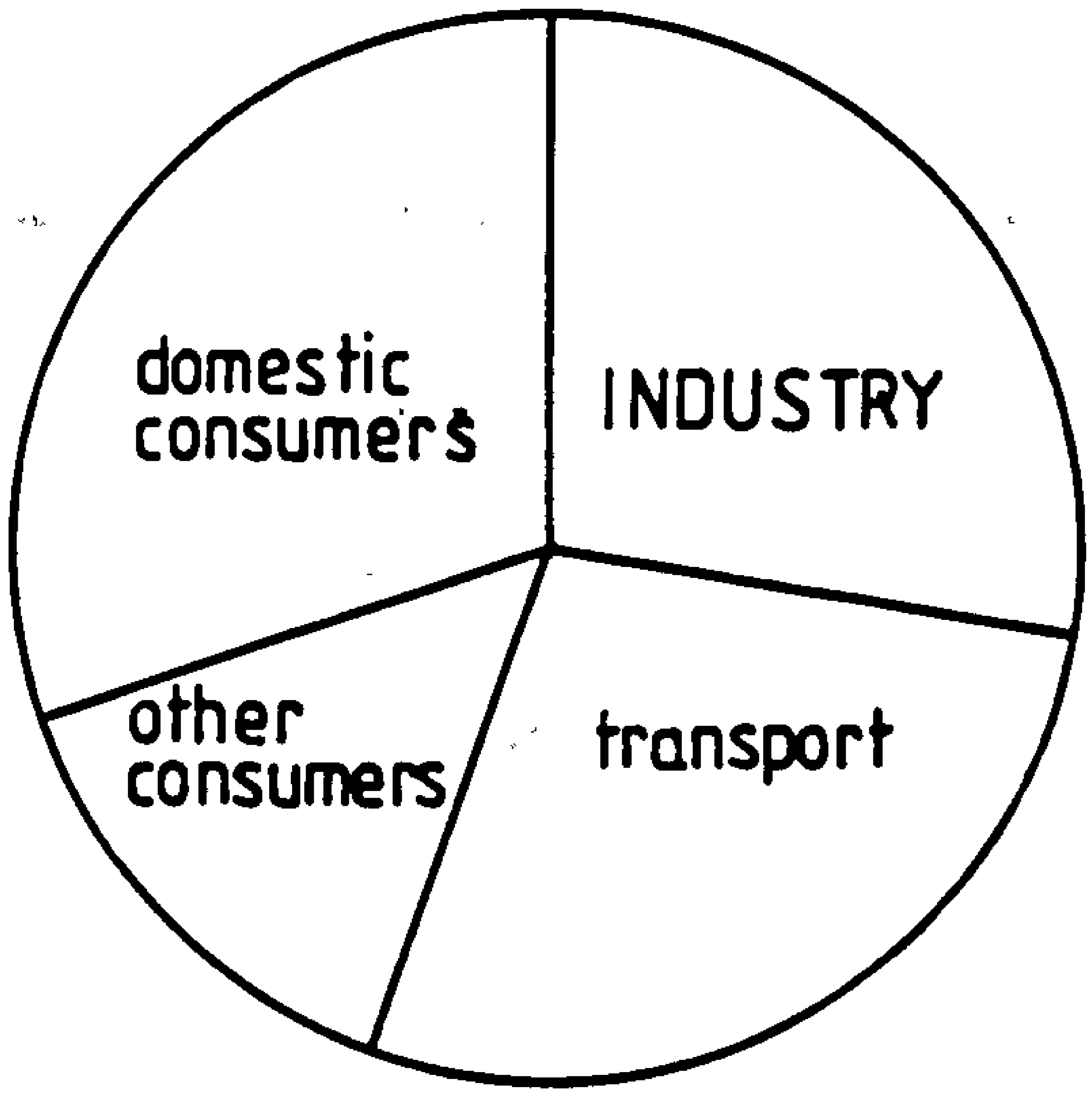


primary fuel	mtce	%
coal	113·5	33·9
petroleum	112·6	33·6
nat. gas	83·6	24·9
nuclear electricity	21·3	6·4
hydro electricity	2·4	0·7
imported electricity	1·7	0·5
total	335·2	100

UK. energy consumption of primary fuels 1986

(DOE 1987 (a))

Fig.1.5

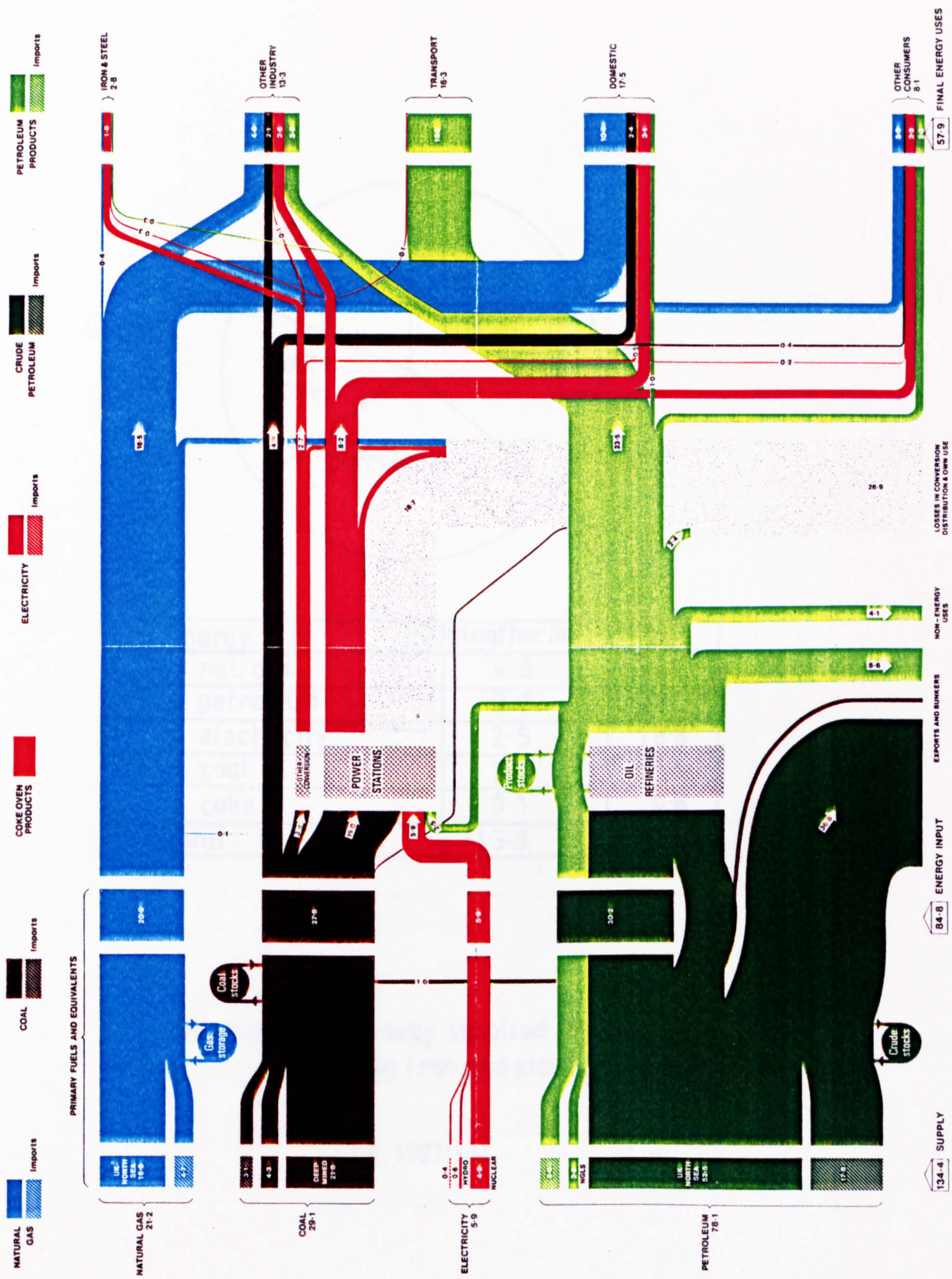


sector		gigatherms	mtce	%
INDUSTRY	iron + steel	2·8	11·2	4·8
	other	13·3	53·2	23·0
transport		16·3	65·2	28·1
domestic consumers		17·5	70	30·2
other consumers		8·1	32·4	13·9
total		57·9	231·6	100

UK. energy supplied to final users 1986

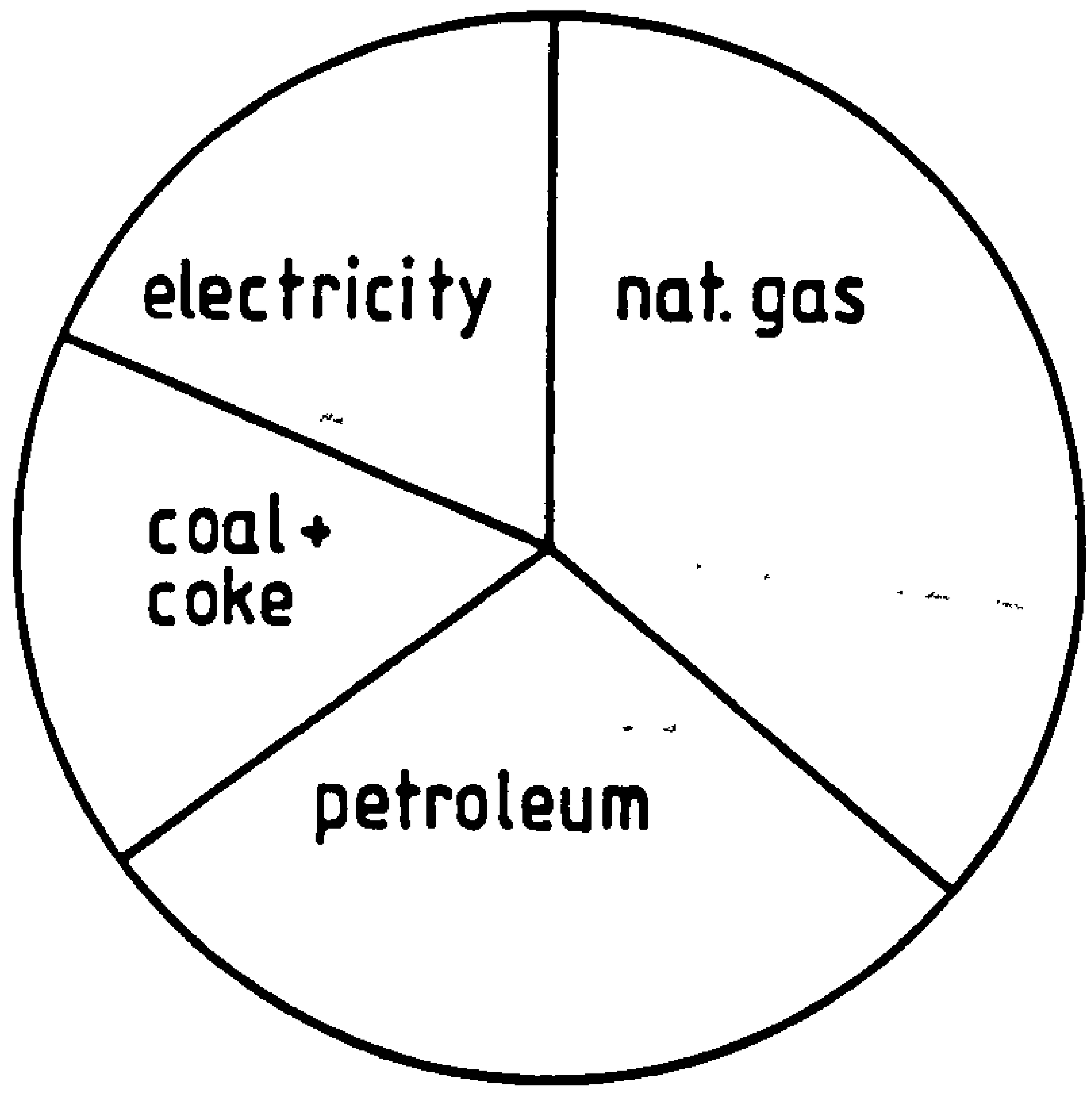
(DOE 1987(a))

Fig.1.6



UK. Energy Flows 1986 (gigatherms)

Fig. 1.7

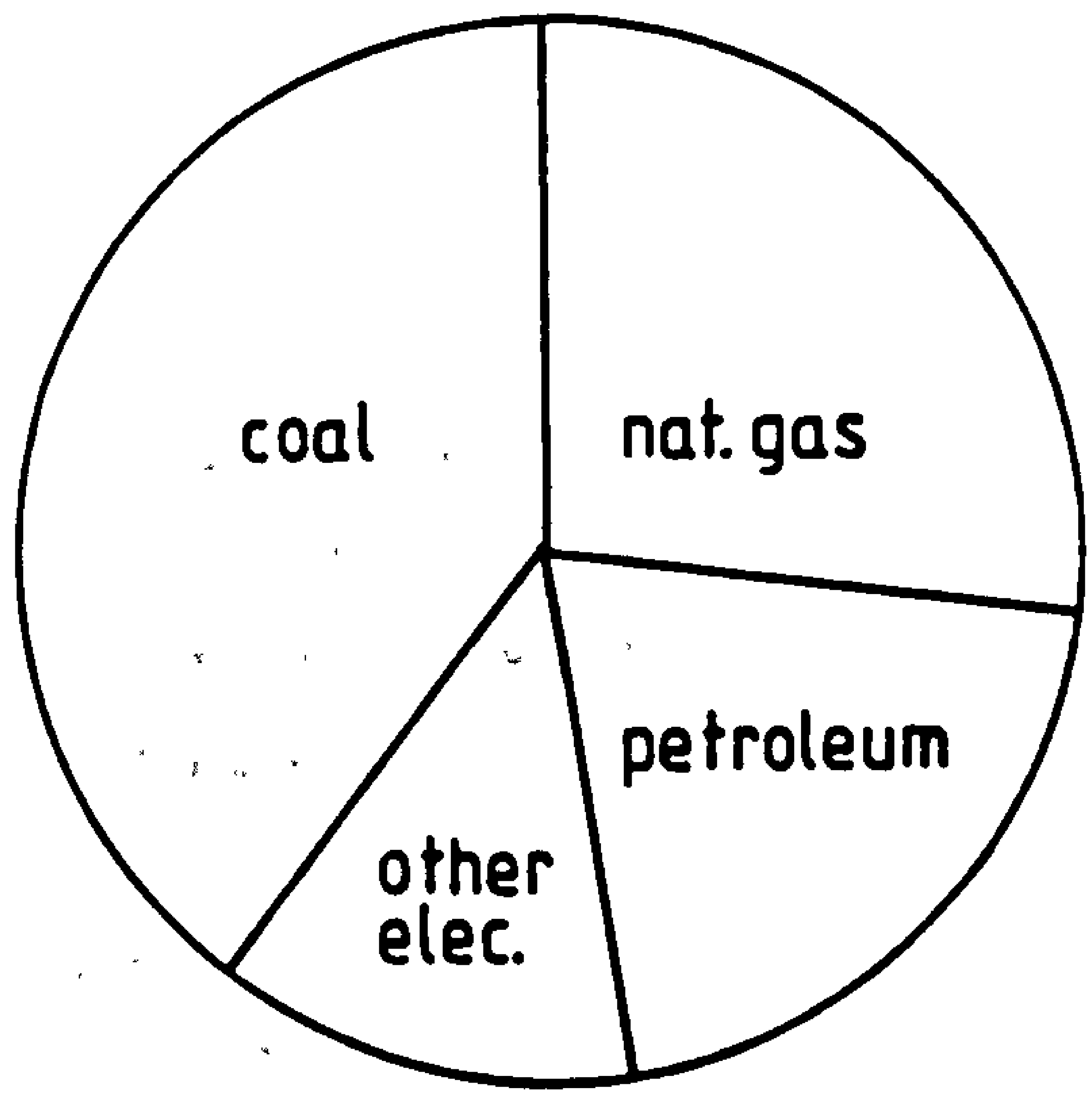


energy type	gigatherms	%
nat. gas	4·8	36
petroleum	3·8	28·6
electricity	2·5	18·8
coal	2·1	15·8
coke	0·1	0·8
total	13·3	100

UK. industrial energy supplied 1986
(excluding iron and steel)

(DOE, 1987(b))

Fig.1.8

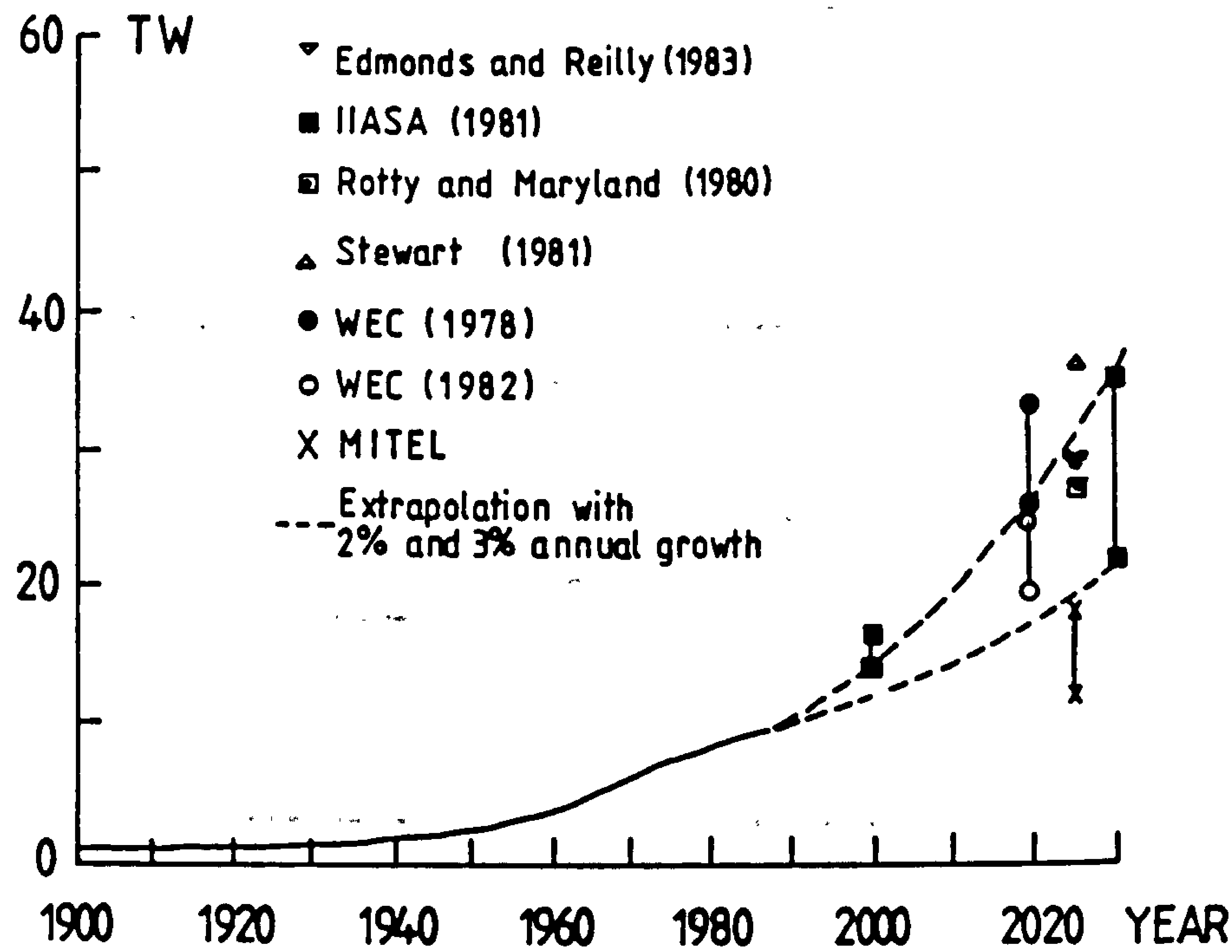


<table>
<tr><th colspan="2">primary fuel</th><th colspan="2">gigatherms</th><th colspan="2">%</th></tr>
<tr><td colspan="2">nat. gas</td><td colspan="2">5·42</td><td colspan="2">26·8</td></tr>
<tr><td colspan="2">petroleum</td><td colspan="2">4·19</td><td colspan="2">20·7</td></tr>
<tr><td rowspan="3">COAL</td><td>direct</td><td>2·1</td><td rowspan="3">8·04</td><td colspan="2" rowspan="2">39·7</td></tr>
<tr><td>coke</td><td>0·14</td></tr>
<tr><td>elec.</td><td>5·8</td><td rowspan="2">41·5</td><td></td></tr>
<tr><td colspan="2">other elec.</td><td colspan="2">2·6</td><td>12·8</td></tr>
<tr><td colspan="2">total</td><td colspan="2">20·25</td><td colspan="2">100</td></tr>
</table>

UK. industrial primary fuel used 1986
(excluding iron and steel)

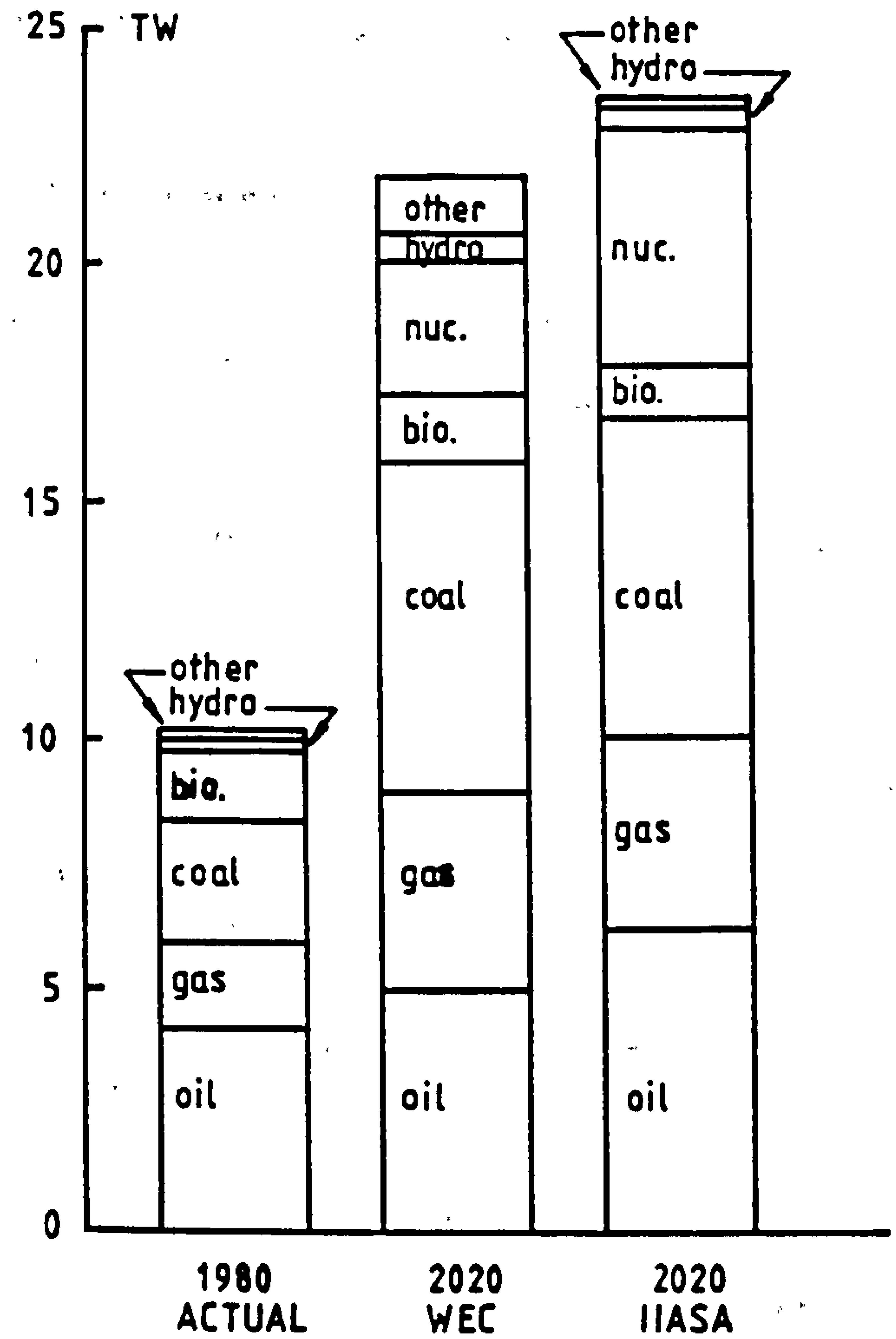
(DOE, 1987(b))

Fig.1.9



World energy use with future projections.
(Johansson, 1987)

Fig. 1.10



Global primary energy consumption, disaggregated by energy source.

(Johansson, 1987)

Fig. 1.11

CHAPTER 2

INDUSTRIAL ENERGY CONSERVATION

2.1 Government Action.

An early realisation, after the 1973 oil crisis, in the U.K., was the almost total lack of detailed knowledge concerning energy use within U.K. industry. Accordingly the IETS (Industrial Energy Thrift Scheme) was initiated in 1976 by the Department of Industry's Energy Unit to: gather information on existing patterns of energy use; gather information on energy saving opportunities and the needs for further research and development directed towards the improvement of energy utilisation and to encourage the more efficient use of energy through improvements in process efficiency and the adoption of good housekeeping practises (DTI, 1988). The work was carried out by research associations and independent consultants and the results of over 2000 industrial visits revealed estimates of potential savings ranging from 9 to 34% of total energy use (Hale, 1979).

It is estimated that of the 100 million pounds that is spent daily in the U.K. on energy, 20 million pounds is wasted (EEO, 1985a). The Energy Efficiency Survey Scheme introduced by the EEO (Energy Efficiency Office) in 1984 in the U.K. was created for non-domestic energy users to identify potential energy savings with the aid of government grants. Short surveys, typically carried out in one day, have been conducted to estimate potential savings that may be realised and as a first step to establishing the potential value of an extended survey. The average savings identified by these surveys amount to 16% of the annual fuel bills (EEO, 1986a). Extended surveys form a more detailed examination of the energy use of a site including the measurement of energy flows and boiler efficiencies and typically extend over several months. Experience indicates that for every one pound invested in such a survey, average energy savings of 30 pounds per year are identified (DOE, 1985b). The uptake of the recommendations of such surveys by the companies involved has been disappointing and the scheme has now been discontinued with the reduction of the EEO's annual budget. The Energy Efficiency Demonstration Scheme has perhaps been more successful. In this scheme the EEO has provided grants to encourage the more widespread adoption of technologies which lead to the more efficient use of energy (EEO, 1986b). The investment costs of the projects have often been hundreds of thousands of pounds and the results have been disseminated by way of project profiles (e.g. EEO,

1987) which detail energy and cost savings with the intention that similar projects may be undertaken by other companies.

2.2 Industrial Energy Conservation - General.

It is not within the scope of this work to discuss industrial energy conservation in general - rather a few references of a general nature are mentioned and the interested reader is directed to the bibliography for further information. There is extensive literature available on this subject much of which has been published since the 1973 oil crisis. Reay (Reay, 1977) discusses energy intensive industries such as iron and steel, pulp and paper and glass as well as examining heat recovery techniques and energy storage. Meckler (Meckler, 1984) includes energy analysis techniques and case studies of retrofitting for industry. O' Callaghan (O' Callaghan, 1979) discusses a range of topics from energy analysis and management to heat recovery from flue gases. Amman (Amman, 1981), editing the proceedings of The Fourth International School of Energetics, held in 1980, includes papers on data collection methodologies and the application of technology for industrial conservation. An extensive collection of papers covering low and medium temperature heat recovery, combustion efficiency, energy management principles which is particularly strong on case studies of energy conservation (Thumann, 1981) forms the proceedings of the Fourth World Energy Engineering Congress, 1981.

2.3 Industrial Energy Conservation - Barriers.

With the benefit of some 15 years hindsight since the 1973 oil crisis and the publication of numerous case histories of industrial energy conservation programmes and the results of government assisted schemes, it is evident that the barriers to reducing industrial energy use are not of a technical nature. Furthermore, it is rather surprising that, during the recession of the early 1980's in the U.K., the lack of capital for investment in energy conservation was not considered a problem. From a sample of 29 companies, considering conservation proposals, 24 reported capital was available if the proposal could be justified and only two companies reported no capital for such measures (DOE, 1982). This and other surveys indicate that the barriers are not primarily financial either. It appears that the most intangible, and consequently the most difficult of the barriers to energy conservation in industry involves management attitudes, practises and policies. Energy auditing procedures usually include investment appraisal techniques for justifying and prioritising conservation strategies but it is evident that an economically favourable proposal is no guarantee of success. A survey of 156 firms in Georgia which had extensive plant energy audits over a four year period followed by extensive data collection relating to: management structure; decision making procedures; plant responses to specific energy audit recommendations and planned energy conservation investments was carried out. The survey made the important conclusion that conventional investment analysis does not explain the energy conservation activities (Sassone, 1984). It is further concluded that whilst energy conservation decision making does not follow the classically rational discounted cash flow approach, neither is it actively irrational. Rather, due to low priority and low visibility, energy conservation is neglected by top management. In many firms, it is not a question of good or bad decisions but of no decisions at all (Sassone, 1984).

A proposed explanation takes a broad view of the energy conservation decision process, placing it in the context of all available cost control options available at the plant level. Typically, labour, equipment, facilities, raw materials and other costs dominate energy costs and unless managers feel that cost control opportunities in these more substantive cost categories have been exploited, energy conservation proposals are not likely to capture their attention. For example, if labour costs could be reduced by 1% through closer supervision of production staff, with little investment, saving even 10% of energy costs through a large investment would seem unattractive by comparison. Such attitudes have been observed in the plant surveyed in this work where cost savings have been realised by the reduction of staff, particularly those with a maintenance function, and the redeployment of others. For the plant surveyed the energy cost is less than 1% of the product value and the savings which have been identified, of the order of hundreds of thousands of pounds, continue to merit little interest. There is, in general, a second fundamental reason why energy conservation proposals may not attract the interest that a favourable cost - benefit analysis implies. Conventional economic theory accepts profit maximisation as the goal of the firm whereby cost savings and revenue enhancements produce the same effect. An alternative to the conventional theory is one which places emphasis on market share maximisation subject to earning reasonable profits and in this case revenue enhancements advance the objective of increasing market share but cost savings do not and hence are not held in the same regard. In reality, firms seldom have a single corporate objective but rather aspire to a combination of them relating to profit, revenue, market share and so on. However, it still appears that cost savings are rarely strictly preferable to revenue enhancements but revenue enhancements may often be strictly preferable to cost savings and cost saving energy conservation proposals which address a relatively small fraction of total costs may appear even less favourable. This exemplifies the simplistic accounting procedures omnipresent in industry, which were mentioned in section 1.6.

It has often been noted that top management commitment is a prerequisite to the implementation of a successful energy management programme. Whilst this is true, it appears that, in most cases, such commitment is a function of energy costs only and often conservation programmes have waned with declining energy costs. As a result, the most often implemented energy conservation measures are those that require little capital or technical input , the quick fix, or those which can be implemented by a plant energy manager without top management involvement. In the current climate of low energy prices, proposals requiring top management approval often fail. At the plant studied, proposals to modernise the boiler house instrumentation have failed for this reason.

2.4 Analysing energy use.

Attempts to reduce the energy consumption of a plant, frequently begin with some form of energy analysis which aims to identify the separate energy flows within a plant. Whilst easily stated, the execution of such a task in a detailed way, for a large plant, such as the one surveyed in this work, would take a number of man-years of work and require considerable expenditure on monitoring equipment, installation, cabling etc. Such an approach, rarely if ever taken, is mentioned because it may be taken as the definitive analysis. It is questionable as to whether such a comprehensive detailed analysis is desirable from a conservation standpoint and most unlikely to be accepted from an economic one. In reality, analyses of energy use cover a broad range of options from the one day short survey as mentioned in section 2.1 to a detailed analysis of a single or group of similar plant items, such as boilers, compressors and ventilation fans, or a single system such as lighting, heating and compressed air.

The work here is concerned with both the general analysis of energy use for the entire plant and the detailed analysis of energy use for the boiler plant only and is described in later chapters.

2.5 Energy Auditing.

An energy audit is a combination of an analysis of energy consumption and the economic interpretation of the resulting conservation options. The term audit, derived from financial accounting practise, implies the consideration of input and output energy flows to and from the plant, or system considered. By attempting to equalise these flows within the constraints of the analytical procedures adopted, the energy audit (audit) defines the characteristic energy usage of the plant or system. However, the term energy audit continues to be used in a rather general sense and is applied to procedures ranging in extent from a one day inspection of a building or plant with preliminary recommendations, often based on the auditor's past experience, to a lengthy, detailed analysis involving monitoring of discrete energy consuming sub-systems with detailed engineering and financial analysis of potential conservation options. Much of the early work relating to energy auditing was carried out in the USA in the 1970's and the term energy audit was used by the United States Department of Energy in 1977 in connection with the Supplemental State Energy Programme (SSEP). The Federal Register defined three classes of audits to be employed in the SSEP which differed in the way by which the audit was accomplished namely:-

Class A required an on-site visit by an auditor and his evaluation.
Class B required that the building owner completed a questionnaire which was evaluated by an auditor.
Class C was performed by the building owner himself with help from Department of Energy published workbooks.

Within this programme, carrying out energy audits enabled the state to qualify for federal funding and thus the audit terminology developed with financial assistance or funding in mind. The SSEP gives a technically concise definition viz: 'the energy audit serves to identify all of the energy streams into a facility and to quantify energy use according to discrete functions'. A second definition compares the process to the closing statement of an accounting system whereby: one series of entries consists of amounts of energy which were consumed during the month in the form of electricity, gas, fuel oil and steam and a second series lists how the energy was used: how much for lighting; in air conditioning; in heating etc., and, unlike the first definition, makes reference to conservation opportunities in that the energy audit process must be carried out accurately enough to identify and qualify the energy and cost savings that are likely to be realised through investment in an energy-savings measure. Thumann (Thumann, 1983) includes the essential elements of the preceding two definitions and gives a simple working definition viz: an energy audit serves the purpose of identifying where a building or plant facility uses energy and identifies energy conservation opportunities. The National Energy Conservation Policy Act of 1978 which made almost $1 billion of funding available for energy audits of schools, hospitals and public buildings defined three energy auditing procedures viz: (1) the preliminary audit gathers basic information only; (2) the energy audit aims at implementing no-cost and low-cost conservation measures; (3) the technical assistance energy audit considers all possible energy conservation measures and includes a detailed engineering and cost analysis.

Whilst numerous definitions of the 'energy audit' have been adopted by practitioners, it is prudent to consider the term as a generic one and to recognise the essential element of all audits as an investigation which aims to account for the energy consumption of a system with the intention of reducing it.

Energy audits may suffer from several limitations which reduce their potential effectiveness viz:
(1) cost and potential client's attitudes;
(2) the inaccuracies involved in the computation of energy consumption and
(3) the uncertainties associated with cost estimating.
These limitations are discussed below.
(1) An energy audit is often perceived as an expense with no tangible benefit and, with relatively low energy prices, many consumers are not motivated by themselves to pay for such a service. When financial assistance is provided - as in the recently ended DOE scheme offering 250 pounds towards the cost of a short survey and up to 10,000 pounds towards the cost of an extended survey - motivation may increase but, as previously mentioned, experience shows the uptake of recommendations from many such funded surveys to be low. Possible reasons for this have already been discussed in section 2.3.
(2) A fundamental limitation is incurred by the techniques available for the computation of energy losses (Bickle, 1983) in buildings and the practical assessment of the energy used by discrete systems such as lighting and ventilation fans. The savings associated with a specific action may be of the same order as uncertainties involved in the estimation procedures. Input data such as internal and external temperatures, effective in-situ U-values, air change rates and assumed plant efficiencies contain many uncertainties and approximations which may be compounded by the absence of data relating to operating periods, occupant use patterns and the existence of a specific micro-climate for an individual building (Bloomfield, 1985). Even in the absence of such input deficiencies, the reduction of a real building to a

thermal network model relating heat flows to nodal temperatures and assumed conductances, introduces many simplifications with an associated loss of accuracy. The prediction of performance for a combination of conservation measures is difficult. For example, the installation of roof insulation combined with a reduction of space temperature each with an individual 10% energy saving capability would not produce a net saving of 20%, since the reduction in space temperature will reduce the heat flow through the roof and the actual savings attributed to the insulation.
(3) Detailed cost estimating for conservation measures may often be outside the scope of the energy audit and 'budget cost' estimating may rank the cost effectiveness of a marginal strategy incorrectly. Furthermore, since many conservation measures are 'one-off', costs may be uncertain.

Despite these limitations, energy audits of the simplest kind may often identify excessive consumption - as in this work- and provide useful pointers for further analysis. In their simplest form they may be instrumental in increasing management awareness of the relative contributions of each energy type towards the total energy bill and energy consumption during periods of no production.

2.6 Instrumentation.

Energy auditing procedures require items of test equipment such as a digital thermometer, a combustion analyser and a light meter (Payne, 1980). The equipment is generally used for taking 'spot' measurements which are manually recorded and has the advantage of being portable, easy to use, relatively cheap and requires no installation or wiring. If measurements are required over an extended period of time then such equipment may be used but requires periodic attention for recording readings and this may prove time consuming. The disadvantages are more apparent if various items of test equipment are situated over a wide area. Such problems may be alleviated by the use of equipment which will also log data for a period of days or weeks depending on the sampling rates. Such equipment, which is generally battery powered, requires only intermittent attention and may store data on an integral printer as in the Kane -May temperature/humidity recorder or in RAM (random access memory) as in the Solomat MPM logger which may then be downloaded to a personal computer via an RS232 or IEEE interface. If a number of parameters are to be logged over an extended period of time then a personal computer connected to a data logger such as a Fluke or Solatron which will log about 100 channels provides a versatile system. Such an approach has the advantage that data may be displayed in real time and continuous logging may be performed as a background function. The system may be programmed to store data periodically and may be left to run for long periods with no operator intervention. Such a system has been used in this work and is described in detail in a later chapter.

Existing plant instrumentation may prove useful for measuring energy flows but is rarely sufficient and often unreliable. The present study encountered a number of problems in this area: digital counters which stuck and counted only every third or fourth pulse; fluctuating analogue meters; poorly calibrated oxygen sensors; non-functioning meters and chart recorders; a gas flow reading low by a factor of 10; 12" and 8" HPHW (high pressure hot water) flow readings high by a factor of 10 and reversed and boiler efficiency displays incorrect by several percent. The installation and/or repair of instrumentation is often restricted to times when the plant is not operating and for flow meters in large HPHW process mains this may occur only annually.

The problems associated with instrumentation, some of which have been mentioned above are probably the most serious to be encountered in attempting an analysis of industrial energy consumption and account partly for the paucity of reliable data which is available.

2.7 Energy Management Systems.

These systems offer great potential to improve the efficiency of energy utilisation as they may typically reduce the energy consumption of a building by 10 to 30% (ETSU,1986). A mean reduction of 20% by the use of industrial monitoring and control could lead to savings of 6% in the total U.K. energy usage. There are numerous case histories of the successful implementation of energy management systems. (Thumann, 1981; ETSU, 1986) but their present uptake is less than 1% of the total market partly because of the barriers which were previously discussed and partly because they invariably require large capital investment. However pay-back periods of less than three years have been reported by the US Association of Energy Engineers for 80% of existing installations. Their utility stems from their ability to perform many functions such as: automatic switching of plant; optimisation of plant operation; monitoring plant status and environmental conditions and providing energy management information. However, the effectiveness of such a system to reduce energy consumption whilst maintaining acceptable conditions requires considerable time and expertise after their installation. This has often been overlooked in the past and frequently companies have had systems installed which were considered unsatisfactory simply because they were not commissioned correctly. At the plant studied in this work, it was a common practise for controls to be switched from 'auto' to manual by employees with the result that system control was lost.

Early energy management systems had limited data display capability (e.g. Honeywell Delta systems) restricted to text and figures only. Recent developments (Satchwell, 1986 and Trend, 1987) have enabled graphical data output along with text and figures as well as dynamic mimic displays. Real time monitoring with graphical output is probably the best way to investigate energy use as a function of environmental factors and production rates etc. so these improvements to the display capabilities of energy management systems will have a beneficial effect on the energy efficiency of a plant. With recent developments in electronics and computing, the MMIs (man-machine interfaces) for many early e.m.s. (energy management systems) are now out of date and the addition of a personal computer with communications/display software would improve data display enormously. Another problem, evident at the plant studied, was that the company was heavily dependent upon the e.m.s. installer for after sales service and this left much to be desired.

2.8 Monitoring and Targeting.

A recent approach to improving industrial energy utilisation is the monitoring and targeting of energy use for energy efficiency. It is assumed (EEO, 1986(c)) that the foundation of effective energy management is a system of monitoring and targeting to equip firms with the information and the motivation to attain lower levels of energy use. The EEO stress greater energy efficiency as a means of increasing profits. Whilst energy costs for a company may be small in comparison with others, as discussed in section 2.3, every 10,000 pounds saved in energy costs will, in general, yield an extra 10,000 pounds in profits. For the average British company to achieve a similar increase in profits from output alone would require a rise in sales of some 120,000 pounds (EEO, 1986(c)). The M & T (Monitoring and Targeting) approach assumes that energy must, in common with other resources such as finance and manpower, be managed as a controllable resource. This requires that energy use is accurately measured and targets of use are then established to motivate staff to seek to improve performance to reach and possibly surpass these targets by modifying operational procedures. Companies have found that the introduction of M & T systems alone can lead to savings of 10% in their energy consumption.

Chapters five and six of this thesis describe the M & T system developed for the boilerhouse at the plant studied.

CHAPTER 3

GENERAL ANALYSIS DESCRIPTION

3.1 Introduction.

As previously stated, an energy audit or survey should be a prerequisite for any attempt to increase the energy efficiency of a building or plant. The common aims of all energy auditing procedures are firstly to determine the current rate of energy consumption (typically for a twelve month period) and secondly to identify processes where energy wastage may be reduced. These require further refinements namely: (i) an analysis of consumption by energy type (e.g. gas, oil or electricity), the components possibly being related to degree day data and/or, in an industrial case, to the rate of productive output; and (ii) an analysis of the rates of energy loss from energy conversion equipment, distribution ,mains and buildings.

This chapter describes a suite of computer programs which enable the production of pertinent tabular and graphical output, annotated with diagram numbers, as necessary, which when added to specific text, constitute a 'first order' energy audit or general survey. The model used is very simple, assuming steady state conditions with a constant internal temperature and constant external temperatures for each month of the year. The model assumes that all the energy supplied to the buildings is lost as heat through ventilation and fabric losses. Dynamic effects and solar gains are neglected as the inclusion of them would require procedures which are outside of the scope of the intended approach. In view of the limitations of all energy audit procedures, mentioned in section 2.5, the validity of a more sophisticated model which included such secondary effects is questionable. Previous work (Delorme, 1980) suggests that many dynamic features are relatively unimportant if long term energy consumption is of primary interest as it is here. The applications and limitations of thermal models have been researched at some length. Allen (Allen, 1986) in examining a number of large dynamic simulation models as well as some simpler methods found significant discrepancies in the predictions of energy requirements for a well-defined building subject to a number of design changes. Spielvogel (Spielvogel, 1978) points out that whilst computer techniques give the potential to model extremely complex phenomena, the application of such techniques to inappropriate problems can produce useless results. Similarly, Holmes (Holmes, 1986) states a golden rule which says 'the model must be suitable for the intended application'. Since the intention here is not to model complex thermal phenomena but to identify, in an approximate way, how energy is utilised, it is believed that the simple approach is justified. The observations regarding energy conservation which have been made on the basis of this model are taken as further justification of this approach.

3.2 Preliminary Considerations.

A primary aim of the project was to investigate the extent to which computerised techniques may be usefully employed to produce an energy audit report. A report which was entirely generated by computer was firstly considered whereby graphical output and derived parameters such as mean site U value and energy consumption per production unit could be produced from input data. The program would utilise an expert system to infer recommendations for energy saving options by comparing the derived parameters with others contained in a database of information. Parameters derived from the input data would be compared with an 'acceptable range' for the relevant parameter from the database. If the parameter fell outside of this range, a flag would be set causing the relevant recommendation(s), held in the database, to be output. For example, a derived mean site U value of 1.7 watts/sq.m/C which fell outside an acceptable range of (say) less than 1.5 watts/sq.m/C would prompt the program to output:-
Mean site U value 13% higher than acceptable maximum - recommend following possible actions: (1) Reduce roof glazing (output only if this exists); (2) Increase insulation to roof; (3) Install suspended ceilings; (4) Cavity fill walls (output only if walls of cavity construction).
It is considered that such a system would, at least, act as an 'aide memoir' to a practising energy manager/consultant or as a guide for a less experienced person wishing to investigate energy saving options and it would probably be easier to use a system of interactive software which enables rapid presentation of specifically relevant information than to use one or more reference guides (e.g. HMSO, 1984, Payne, 1980 and NIFES, 1984) which, by their very nature, contain much information, irrelevant to the user's specific needs. The system could be extended to include the economic appraisal and ranking of the various options. The development of such a system was not followed here for several reasons: (1) the software involved was outside the scope of the intended work; (2) construction of a database would require extensive practical auditing experience; (3) for a moderately sized database, the recommendations would be of a general nature which is of limited interest to most companies and (4) for the purposes of producing an audit report to be read by a

variety of personnel, some of whom are not technically trained, the absence of written text as distinct from fixed format computer output statements is considered a disadvantage.

3.3 The Audit System Used.

In view of the limitations mentioned above the general survey energy audit was produced using a personal computer to:-
(1) manipulate input data and produce derived parameters,
(2) produce graphics for screen or hard copy output and
(3) print the results of the building surveys in tabular form.
The main text of the report, including the recommendations was produced manually.

3.4 Hardware.

A Commodore 64 (C64) personal computer with a single disc drive (1541) was used to develop all of the software used in the production of the energy audit. This enabled screen output using high resolution graphics and hardcopy output via a Commodore MPS 1000 printer. Unfortunately the C64 does not have a standard IEEE 488 (IEEE) output bus required to communicate with the Hewlett-Packard HP7475A six pen colour plotter which was used for producing hardcopy of colour graphics and it was therefore necessary to obtain an interface to enable communication between the RS232 serial output of the C64 and the IEEE input of the plotter. The interface obtained (Interpod) was chosen on the basis that it would enable such communication but this subsequently proved to be untrue. Investigation showed that the handshaking protocol of the C64 was incompatible with that of the plotter. During handshake the, C64 sets the data valid (DAV) line low and waits a maximum period (time-out period) of 64 milliseconds for the plotter to reply with a not data accepted (NDAC) signal. Because of the slow response time of the plotter in executing certain instructions, the time-out period may be exceeded and the transfer of further data is inhibited. To overcome this incompatibility, the C64 was linked to a Commodore 8050 double disc drive through the Interpod interface. This enabled files to be transferred from the C64 memory to the 8050 disc drive which could then be accessed using a Commodore Pet 8032 computer (Pet). Unlike the C64, the Pet could communicate with the plotter by extending its time-out period with a single poke instruction (not possible with the C64). The complete system is shown in fig. 3.1 which enables:-
(1) output, including colour graphics, to the screen of the C64,

(2) hardcopy printed output via the MPS 1000 printer and
(3) colour graphics hardcopy via the HP7475A plotter.
In transferring files from the C64 to the Pet, it was necessary to:-
(1) Run a short program changing the device number of the 1541 disc drive from 8 to 9 (Interpod, 1986).
(2) Run a Pet emulation program on the C64 so that files were saved in a format acceptable to the Pet (West, 1985).

3.5 Software.

The software written in Commodore basic was developed to:-
(1) input and process data,
(2) produce printed hardcopy for the report in tabular form and
(3) produce hardcopy for the report in graphical form.
It was considered advantageous to develop the software in conjunction with a real energy audit procedure rather than on the basis of a model procedure. Accordingly a large manufacturing plant was chosen as a development environment. It was considered suitable because:-
(1) energy usage and cost data for a recent twelve month period were readily available,
(2) the plant utilised several different energy types,
(3) consumption was spread over a number of buildings and
(4) software which could accommodate an analysis of this plant would probably be suitable, with perhaps minor modifications, for other plants.

The individual programs used in the audit are described briefly below in terms of input, operation and output.

3.5.1 Program INENCOST

Input.

(1) The number of energy types to be considered and the month to be chosen as month number one.
(2) Monthly data on productive output.
(3) Monthly environmental data in the form of degree-days and average outside air temperature.
(4) Energy type descriptors, units of measurement and monthly consumption and cost figures for each energy type.

Operation.

(1) Prompts are displayed which enable all data to be input.
(2) Each energy type is referred to by a descriptor

(e.g. Elec for electricity) with its own units of measurement used for input.
(3) All energy units are converted to Kwh (kilowatt-hours) and cost data is in pounds sterling.
(4) Data, having been input may be corrected if necessary.

Output.

(1) All data is filed to disc with the file name prefix INCO.
(2) Total annual usage, cost and cost per kWh are displayed on the screen for each energy type.

3.5.2 Program HISTOGRAM

Input. File INCO.

Operation.

(1) Two separate histograms namely: the monthly energy usage; and monthly energy cost for a twelve month period are plotted.
(2) The output plots may relate to a single energy type or any combination of energy types as specified by the user from a menu. If a combination of energy types is plotted, the usage and cost components for each type may be displayed in different colours.

Output.

Histogram displays to: screen in colour; printer in black and white; or plotter in colour as required.

3.5.3 Program PIE

Input. File INCO.

Operation.

Pie chart plots of energy usage and cost for a twelve month period for any combination of two or more energy types may be selected from the menu.

Output.

Pie chart plots for both annual energy usage and cost for a twelve month period including contributions, in absolute terms (in either kWh or pounds) and as a percentage, from each energy type towards the totals.

3.5.4 Program KWHDEGDAY

Input File INCO.

Operation.

(1) A plot of the energy used against the number of degree-days for each month extending over one or two years is produced.
(2) The energy used may relate to one or a combination of energy types as specified by the user.
(3) The energy used for each month may be divided by a parameter representing the monthly productive output, if required.
(4) Regression lines may be defined and displayed for the energy usage data for any combination of months spanning one or two years. This facility enables different regression lines to be displayed when changes in energy usage occur as a result of the installation of new plant or buildings.
(5) Trend lines may be displayed.
(6) The plotter output enables the points displayed to be identified by month and year (when more than one year's data is plotted) and different regression lines to be identified by colour and a brief description.

Output.

This may be presented on a screen, on a printer or the colour plotter.

3.5.5 Program EXSUR

Input.

Fabric and ventilation data for each building considered is entered.

Operation.

(1) The program displays prompts to assist the entry of data. Each building surveyed, identified by a descriptor, is considered as made up from a number of component faces. Each face is either a wall (W), a roof (R) or a base (B). In the case of a wall, an orientation is also included.
(2) Each component face may be divided into a number of elements so that, for example, a wall comprising of areas of glass, 9 inch brickwork and uninsulated cladding would be defined in terms of these three elements. Each element of a face is referred to by a descriptor mnemonic, which relates to the composition of the element and defines it's U value. When an element descriptor is entered, it is compared with descriptors held by the program and the appropriate U value is identified and displayed. If the descriptor is not held, the program prompts for information on the new descriptor. Entry of this data is followed by return to the main program. The area of each element may be entered directly if this has been measured in the survey or calculated from the length and height

entered separately. The product of the area and the U value is calculated for each element of each face and this is printed in watts per degree C. and as a percentage of the sum of all such products for the building.
(3) During the building survey, a wall or roof may be described in terms of it's percentage glazing, in which case data entry is facilitated by entering '%' instead of an element descriptor. A routine, assuming a face of two elements, then prompts for the glazing percentage, the total area of the face and the non-glazed element descriptor and calculates the product of area and U value for each of the two elements.
(4) Because the walls of a building often have the same vertical configuration and construction and differ only in length, entering 'ditto' instead of a face descriptor, enables data for a 'repeating face' (i.e. a wall which is similar, in terms of the above definition to one which has been previously entered) to be entered simply by entering the length. The element descriptors, U values and heights are assigned automatically from those entered for the previous face.
(4) Element descriptors and their associated U-values, stored by the program, may be displayed throughout the data entry process by entering '?' when the element descriptor is prompted.

Output.

(1) Output may be directed to the screen or to the printer for report hard copy (RHC).
(2) The fabric and ventilation data is filed to the disc-drive with the file name suffix SUR.

3.5.6 Program TOTSUR

Input.

This program takes as input the output files from the program EXSUR for each building considered as well as the average monthly external temperatures from the file INCO.

Operation.

(1) The fabric and ventilation data from each building file (...SUR) is aggregated to produce the overall building data, stored to disc in the file ALLSUR, in watts per degree C. A breakdown of the overall building data into ventilation losses and fabric losses (which is subdivided for each element) is made.
(2) Using average monthly external temperatures and an input value for the average internal temperature, the monthly ventilation and fabric losses in kWh for the whole site are calculated and filed in the file

TOTLOAD.

Output.

(1) File ALLSUR is stored to disc with hard copy, if required, to the printer.
(2) File TOTLOAD is stored to disc, in the same format as file INCO so that fabric and ventilation data may be displayed using the programs PIE and HISTOGRAM.

3.5.7 Program AUDIT

Input.

(1) Energy usage data from the file INCO.
(2) Ventilation and fabric data including the breakdown from the file ALLSUR.
(3) Conversion and distribution efficiencies of equipment such as boilers and compressors are entered from a file called CON/DIST EFF.

Operation.

For a period of one year:
(1) For each energy type, the conversion and distribution efficiencies of equipment is entered.
(2) The program calculates conversion and distribution losses, for each energy type, in MWh (megawatt-hours), as a percentage of the total energy used, in pounds sterling and as a percentage of the total energy cost.
(3) The program sums the total energy available after accounting for all of the conversion and distribution losses.
(4) Using monthly average external temperatures, an input average internal temperature and the survey data for each building, the program calculates the annual energy requirement for each building, divides this into ventilation and fabric losses (including fabric loss breakdown) and expresses these as in (2) above.
(5) The program sums the total annual energy used for each building to produce the total energy to all buildings.
(6) The program calculates the annual residual (i.e. the energy which is not accounted for) as the total energy available after conversion and distribution losses minus the total energy to all buildings (i.e. energy in (3) - energy in (5)).

Output.

A hard copy of the energy audit is produced on the plotter.

The last two programs described are not linked to those above and are not shown on the software map. However the efficiency figure calculated by the program

BOILEREFF is used in the CON/DIST EFF file.

3.5.8 Program BOILEREFF

Input.

The measured flue gas temperature, the excess oxygen in the flue gas and the fuel data.

Operation.

The program calculates the combustion efficiency of the boilers (Maples, 1981).

Output.

Data is displayed on the screen and can be filed to disc or sent to the printer.

3.5.9 Program PLOTMW

Input.

Average hourly electrical power consumptions for one or more days.

Operation.

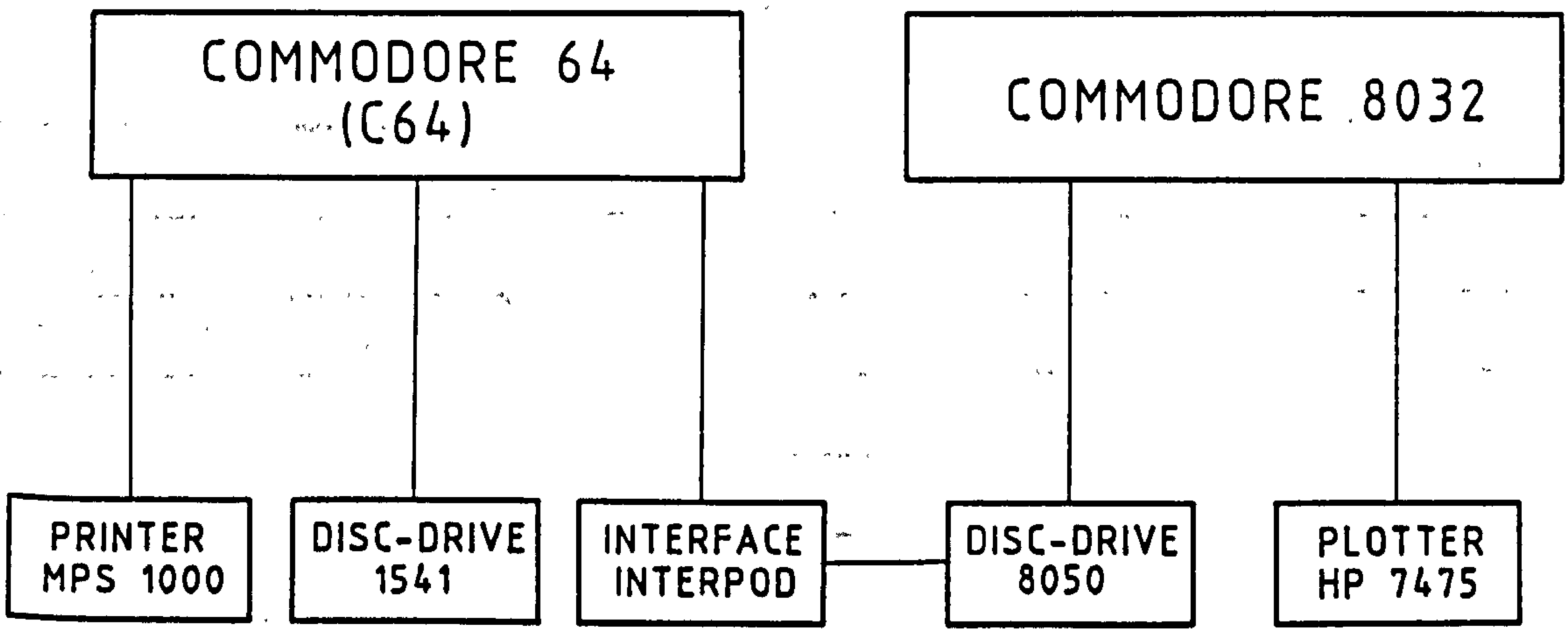
The program plots the variation in electrical power consumption over each day considered.

Output.

A hard copy of the power variation for each day, in a different colour, is sent to the plotter.

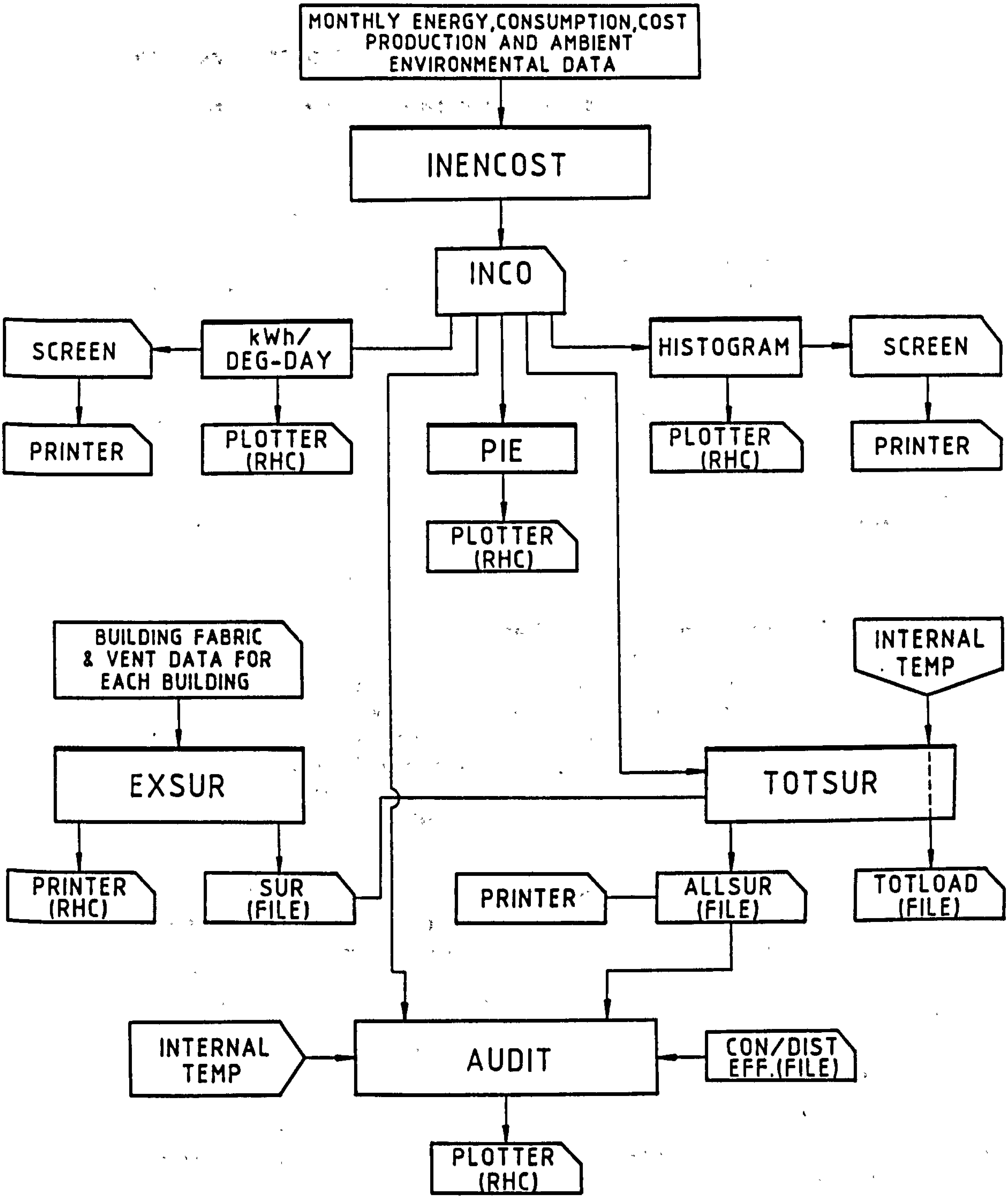
3.6 Software Map.

A software map showing the relationships between the various programs used to produce the energy audit is shown in fig. 3.2. The program outputs are illustrated in the next chapter and the program listings are given in Appendix A.



Hardware used for general analysis

Fig. 3.1



Software map

Fig.3.2

CHAPTER 4

GENERAL ANALYSIS RESULTS

4.1 Introduction.

Examples of the output produced from the suite of computer programs described in chapter 3, for the general energy survey report of the plant are given, together with the observations drawn from them.

This general analysis is primarily intended to heighten management awareness of energy flows and the relative contributions from each energy type towards the total annual consumption and cost. Further, it aims to identify potential areas for reducing energy consumption by way of changing operational procedures.

4.2 The Plant.

The plant surveyed covers an area of some 270 acres and is occupied by five distinct companies, belonging to one parent company, which share a common supply network whilst remaining separately accountable for their energy usage. There is a large variety of buildings on the site including factory blocks, office blocks, a medical centre, a fire station and numerous others. The largest building, AC block, is over 600 metres long.

Energy is supplied in the form of an interruptible natural gas supply to the boiler house (i.e. the gas supply may be interrupted by the gas board), a firm (i.e. non-interruptible) natural gas supply directly to individual buildings and electricity. The five boilers which are dual fired (gas/oil) are switched to heating oil when the gas supply is interrupted. They are used to produce high pressure hot water (HPHW) at about 180 C and 200 p.s.i., which is used for both heating and process requirements. Separate boilers generate steam. Compressed air is produced mainly by electrically powered centrifugal compressors situated in the boilerhouse. The total energy usage in 1986 was approximately 600 million kilowatt-hours costing approximately 9.7 million.

4.3 Building Survey.

Reference to fig. 3.2 shows that the program EXSUR takes as input building fabric and ventilation data and produces report hard copy (RHC), via the printer for each building considered. Fig. 4.1 shows the output for building AC, one of the buildings surveyed (all units are SI). The output includes a breakdown of fabric losses, descriptions of the element mnemonics, ventilation and total losses. This building is divided into 16 faces, 12 of which are walls. For example, face number 4 is a south westerly wall which comprises of three elements: HCC (hollow concrete block); SG (single glazing); and CAL (cladding/asbestos liner). It can be seen for this wall that the sum of the products of the area and U value for each of the three elements is 2% of the total. For other faces, a 0 in the length and height column is attributed to the fact that the element area was input directly. It is immediately apparent from this fabric data that the major contribution towards the conducted heat loss occurs through the roof, with over 32% of the total loss being attributed to the roof single glazing alone. This data enables priorities for reducing heat loss to be identified. The ventilation load is calculated in the usual way and given in watts per degree C. It can be seen that the ventilation load for this building is significantly greater than the fabric load, as indicated by the low fabric/ ventilation ratio. Hence, a reduction in the air change rate of only 0.5 air changes per hour would reduce heat losses more than the most comprehensive insulation modifications. This is characteristic of most industrial buildings - the losses due to ventilation generally exceed those due to the fabric. The sum of the fabric and ventilation losses - the total load - is given at the bottom of fig. 4.1.

4.4 Total Energy Analysis.

The main energy components used at the plant are electricity, interruptible gas and firm gas. Electricity is sub-divided into that used for compressed air generation and that used for all other purposes. The interruptible gas is sub-divided into: gas used for production processes; gas used for the space heating of buildings; and that used for steam generation. This subdivision is not strictly correct since 'process gas' is used for steam generation in one block and, because of the mains layout, the space heating of some blocks. The abbreviations used in the figures for the different energy types are explained below.

ELEC/CAIR	electricity for compressed air generation
ELEC	electricity for all other purposes
PROGASINT	Interruptible gas for processes
HTGASINT	Interruptible gas for heating
FIRMGAS	Firm gas supply to buildings
STEAM	Interruptible gas for steam generation

4.4.1 Annual Energy Analysis.

The piecharts shown in fig. 4.2 are produced by program PIE. They represent an annual analysis by energy type of the total energy usage and the total energy cost. It can easily be seen that whilst electricity usage (Elec and Elec/cair) accounts for only 21% of the total usage, electricity cost accounts for 47% of the total cost. Hence a reduction of only 10% in energy usage (i.e. 2.1% of the total energy) would lead to a reduction of 4.7% in the total energy cost (i.e. 458,000 pounds). It is considered that such cost savings could be approached by improved 'housekeeping methods' and the enhancement of the existing control facilities.

Unlike electricity, an expensive form of energy, gas is relatively cheap and this is illustrated for example by the process gas (Progasint). Whilst process gas usage represents 36% of the total usage, process gas cost represents only 23% of the total cost. A similar ratio exists for heating gas and firmgas but not for gas used for steam generation where the usage and cost figures are both 4%. This low usage/cost ratio for steam (4/4) could be attributed to the low load factor (10%) for the steam boilers. The efficiency of these boilers has been assumed as 60% in the audit (see later) but this is probably high for boilers at such low load. Since steam usage is small and required in only four or five operations, replacement of the existing oversized equipment with small, high efficiency, steam generators at the point of use would reduce existing conversion losses by approximately 50% (assuming new equipment efficiency of 80%) and eliminate distribution losses. Annual cost savings of .88% (one half of the present conversion losses (see audit)) plus .26% (present distribution losses), i.e. 1.14% would follow. This amounts to about 110,000 pounds.

4.4.2 Monthly Energy Analysis.

The monthly plot for all energy types, produced by the program HISTOGRAM, is shown in fig.4.3, where the variation in monthly energy consumption and cost is clearly apparent. The highest and lowest consumptions occurred in February and July respectively. Since part of the annual closure occurred in July, it is not considered as a representative month for minimum energy usage and June, with a number of working days almost equal to those for February, is considered. Both the usage and cost figures for these winter and summer months differ by a factor greater than two, indicating firstly the extent to which the total energy consumed increases to provide for space heating of buildings and secondly the increased demands of production processes in colder weather. From a conservation standpoint, improved housekeeping and control would reduce absolute values of usage and cost for all months whereas fabric improvement and improved ventilation/infiltration control would reduce the winter/summer ratio from its present value. Monthly variations for individual energy types are considered later.

4.4.3 Monthly Usage and Degree-days.

A simple but approximate way of accounting for the outside temperature variation over the year is by considering monthly usage as a function of degree-days. The program KWH/DEGDAY produced the plot of total monthly energy usage against monthly degree-days shown in fig. 4.4. Months for 1986 are shown in red and those for 1987 are in green. Any point is identified by the abbreviation for the associated month which appears directly above the point which appears in red for 1986 and green for 1987. Since a new building was commissioned in August 1986, the months January to August 1986 are considered separately from those afterwards. The blue regression line shown in the figure relates to the first eight months of 1986 which correlate quite well. The high April figure is associated with gas usage and suggests that this is excessive. The purple regression line relates to the eight months September 1986 to April 1987 which indicates a trend towards increased energy usage associated with the commissioning of the new building.

4.4.4 Monthly Usage/Production and Degree-days.

In an attempt to normalise monthly energy usage with respect to productive output, a plot of monthly usage divided by monthly productive output against degree-days is shown in fig. 4.5. At the plant studied, productive output is measured in credit-hours (CH). This plot is also produced by program KWH/DEGDAY by choosing from the options available. As in the previous plot (fig. 4.4), the two periods January to August 1986 and September 1986 to April 1987 are treated separately. Credit hour normalisation for the first period produces a good line (shown in blue) with the exception of August which had high electricity usage due to commissioning activities in the new block. The purple regression line shows rather more scatter.

4.5 Gas Energy Analysis.

Any combination of energy types may be displayed by the programs PIE, KWH/DEGDAY and HISTOGRAM. In this section, only the gas energy (firm and interruptible) is considered.

4.5.1 Annual Energy Analysis.

The pie charts in fig. 4.6 show that the sum of interruptible process gas (progasint) and heating gas (htgasint) amounts to about 70% of the total gas consumption in terms of usage and cost. All of the process and heating gas is used to fire the HPHW boilers. The overall efficiency of these boilers has been assumed as 79% in the audit and in 1986 they consumed nearly 3.5 million pounds worth of gas. An improvement in the average annual efficiency of 1% would lead to a cost reduction of 1.2% - 41,000 pounds - and this is one of the reasons why these boilers were considered in greater detail in the second half of the work.

4.5.2 Monthly Energy Analysis.

The histogram plots in fig. 4.7 show the variation in gas usage and cost over the year. The months February and June are again compared on the basis of similar numbers of working days. The plot for energy used shows that consumptions differ by a factor of 2.7 for these months. The relatively high February cost figure is associated with the use of heating oil during this month which is not accounted for separately. Note also that there is no heating gas consumption for the five summer months when the heating headers are closed.

4.6 Monthly Usage and Degree-days.

The effects of operational procedures become more apparent when the variation of gas usage with degree-days is considered.

4.6.1 Process gas.

Nine zones within the plant use process gas for space heating and usage figures are strongly dependent upon degree-days for the month. This is illustrated by the plots in fig. 4.8. Since the new building became operational in August 1986, consumption figures after this time are not related to those before. The blue regression line is for the first eight months of 1986 with April and June showing relatively high consumptions. Whilst both of these months are brought more into line with credit hour normalisation, since April is a heating month and heating for most of the plant is continuous, irrespective of credit hours, April still represents a high consumption when compared with the preceding three colder months which correlate well. The purple regression line for September 1986 to April 1987 illustrates a general trend towards higher gas consumption with October and January above the line.

The rapid increase in gas usage from September to October (arrowed) is associated with the onset of space heating when the heating headers are opened to HPHW flow. It appears that this distinct jump in energy use leads to excessive consumption in October and November. If the provision of space heating were controlled incrementally, in line with degree-days, along a trend line from the 'no heating' month of September 1986 to January 1987, a potential energy saving of some 10 million Kwh could be made with associated cost savings in excess of 100,000 pounds for October and November.

4.6.2 Heating gas.

The plot 4.9 shows the dependence on degree-days for heating gas consumption. (No heating gas is used in the new building). Since there is no heating for the months May to September, these five months fall on the axis for degree-days. The regression line for all heating months in 1986 and the four heating months of 1987 is shown in blue. However, consideration of this line is misleading. Since no heating gas is used in May 1986, this month could be considered as a starting point for the optimal trend line from a conservation standpoint. Three heating months lie close to this line and all the others, with the exception of February 1986, lie above it. This suggests significant overheating during the months in the mid degree-day range due to inadequate control and considerable potential for cost savings.

It is evident that no heating at all was required in October since there was none in May and May was a colder month. This results from operational procedures in the boilerhouse not accounting for varying external conditions. Approximate savings which could arise from the improved control of heating gas alone, on this basis, amount to 120,000 pounds i.e. October (35,000), November (45,000) and December (40,000).

4.7 Electrical Energy Analysis.

4.7.1 Annual Analysis.

The pie charts in fig. 4.10 illustrate the breakdown of electricity usage and cost for 1986 in terms of: unitcharge 1; maximum demand charges steps 1 and 2; fixed charge and load management charges. The load management tariff was used for the first three months of 1986 only, before the maximum demand tariff was reintroduced. Unitcharge 2 is a reduced charge which applies to electricity supplied between midnight and 0700 whilst unitcharge 1 applies to that supplied at other times. This plot illustrates that maximum demand charges account for some 4% of the total annual electricity cost. Furthermore, it suggests that the switch from load management tariff to maximum demand tariff was effective in reducing costs.

4.7.2 Monthly Analysis.

The histogram plot in fig. 4.11 shows the variation in electrical consumption over the twelve months and dissaggregates it in terms of the charges mentioned in 4.7.1. Compared with that for gas, the monthly energy consumption is more uniform with a factor of about 1.3 between the minimum demand in May and the maximum demand in October. The monthly cost variation however, shows a marked rise during the winter months owing to the tariff structure. The maximum demand charges in December are particularly punitive - about 140,000 pounds - some 28% of the total December cost. This indicates that strategies to limit the maximum demand, particularly in the winter months, should be investigated.

4.7.3 Daily Analysis.

Fig. 4.12 shows the daily variation in total incoming electrical power for the whole plant over the week 13th to 19th December 1986. The profiles for weekdays are similar with power consumption varying between approximately 13 and 30 Megawatts. To translate these power profiles into monetary terms, one may relate the maximum power consumption of 30 MW (Megawatts) to an expenditure of approximately 1000 pounds per hour. In this case, the area enclosed by each profile directly measures the cost of electricity for that day. It may be noted that, on Sunday 14th December, a day of little productive activity, the average daily power consumption was of the order of 10 MW (i.e. one third of the peak power measured in that week). The electricity consumed was then 240,000 Kwh at a cost of over 8000 pounds. If this Sunday power is representative and could be reduced by 50%, this would lead to savings of over 200,000 pounds per year. The peak power for Tuesday is 1.5 MW higher than the other four weekdays and this alone incurs additional maximum demand charges of some 7000 pounds.

4.8 Energy Audit.

The audit plot assumes an average internal building temperature of 20 C. Several conversion and distribution efficiencies have been assumed where details have not been available. The plot shown in fig. 4.13 traces the energy flows, originating with the six energy types through to the buildings of the plant.

The first energy type shown is electricity and the box to the right entitled Dir(ect) Reject 90 assumes that 90% of the electricity into the plant is converted into heat in and subsequently lost through the buildings. This fraction flows through to the large box entitled Total energy to buildings. The remaining 10% is directly rejected to the outside (e.g. heat energy produced by the electric motors of exhaust fans). The four remaining boxes for electricity give the energy loss represented by the 10% energy directly rejected in four ways viz: (1) in energy units i.e. MWhrs; (2) as a percentage of all incoming energy; (3) in pounds, based on the unit cost of the energy type (in this case electricity) and (4) as a percentage of the total cost of all incoming energy. Other energy types such as process gas (progasint) have a conversion efficiency box which contains the assumed conversion efficiency with its associated boxes indicating conversion losses and a distribution efficiency box with associated boxes giving distribution losses. The distribution efficiency of the heat supplied from firmgas is assumed as 100% with no attendant losses. All of the energy remaining after conversion and distribution losses have been accounted for is summed to give the net energy. From the building analysis, the assumed average internal building temperature and the average monthly external temperatures, the fabric and ventilation losses for each building are calculated and summed to give the total energy to buildings. This figure is subtracted from the net energy mentioned above to give the residual which represents the energy which is not accounted for. The total energy to buildings is then fed to the various buildings considered in the audit and the energy lost through each building is divided into ventilation and fabric losses. The four boxed figures which appear to the right of these two divisions are interpreted as mentioned earlier. The fabric loss for each building is subdivided into five and the figures which appear to the right of these subdivisions sum vertically to give the boxed figures above them. All figures are rounded down so summations of component figures will not generally equate to the sum figure.

The energy losses in the audit plot may be divided into two parts namely (1) those losses incurred due to conversion and distribution inefficiencies and (2) losses from the buildings. The losses in (1) amount to approximately 22% (100 - 73.63 - 4.07) of the total energy used which represents nearly 20% of the total energy cost. In attempting to reduce the total energy used and hence the total cost, this energy inefficiency figure of 22%, representing conversion and distribution inefficiencies, might be considered as that requiring first attention. This may be regarded as the most fundamental loss in the entire system which may be reduced as much as is practically and economically possible with the assurance that any reduction would have no adverse effects elsewhere. Reduction of this energy inefficiency figure would mean that the same total energy to buildings could be supplied with a reduced energy input. A further reason for detailed study of the HPHW boilers results from the contribution they make towards this energy inefficiency figure - over 11% (see energy conversion losses for progasint and htgasint).

The audit plot shows that the energy to buildings is some 74% of the total energy supplied and represents 76% of the total energy cost. This figure includes all of the energy entering the buildings and it consists of energy for processes, lighting, equipment, heating etc. It can be seen that much of this loss results from ventilation, particularly in AC block, hence this appears to be a priority area for conservation efforts.

4.9 Recommendations Adopted.

Recommendations adopted since the general survey was carried out include:

(i) Re-routing the compressors' inlet air supply so that air is taken from outside (previously taken from inside) the boilerhouse.
(ii) Removal of the centralised steam generation boilers.
(iii) Detailed investigation of the long term efficiency of the HPHW boilers with a view to conserving energy has been initiated. This project is described in later chapters.
(iv) Twenty mains HPHW valves are being motorised to enable better control of HPHW flows.
(v) The upgrading of the energy management system MMI (man-machine interface) is being carried out.
(vi) The maintenance of instrument function and accuracy and the extension of the existing energy management system are the subject of ongoing work.
(vii) The improved control of electricity consumption outside of working hours is being considered.

BUILDING REF AC 6/3

FABRIC DATA

FACE	DESCR	ELEM	DESCR	LENGTH	HEIGHT	AREA	U	U*AREA	%TOT
1	W(SW)	1	IW	110	30.5	3355	.6	2013	.3
2	W(NW)	1	IW	220	30.5	6710	.6	4026	.7
3	W(NW)	1	UAS	256	24	6144	5.3	32563	6.2
4	W(SW)	1	HCC	152	8	1216	2	2432	.4
4	W(SW)	2	SG	152	4	608	5.6	3404	.6
4	W(SW)	3	CAL	152	12	1824	3	5472	1
5	W(NW)	1	HCC	195	8	1560	2	3120	.6
5	W(NW)	2	SG	195	4	780	5.6	4368	.8
5	W(NW)	3	CAL	195	12	2340	3	7020	1.3
6	W(NE)	1	UAS	0	0	3283	5.3	17399	3.3
6	W(NE)	2	SG	0	0	364	5.6	2038	.3
7	W(NE)	1	CB	0	0	2366	1.5	3549	.6
7	W(NE)	2	SG	0	0	417	5.6	2335	.4
8	W(E)	1	CB	0	0	2488	1.5	3732	.7
8	W(E)	2	SG	0	0	438	5.6	2455	.4
9	W(S)	1	CB	0	0	1998	1.5	2998	.5
9	W(S)	2	SG	0	0	352	5.6	1972	.3
10	W(SE)	1	UAS/SG	326	24	7824	5.6	43814	8.4
11	W(SE)	1	IW	219	30.5	6679	.6	4007	.7
12	W(NE)	1	IW	110	6.5	715	.6	429	0
13	R()	1	INSR	0	0	24080	1	24080	4.6
14	B()	1	UB	0	0	24080	2	48160	9.2
15	R()	1	COMPR	0	0	27450	2	54900	10.5
15	R()	2	COMPR	0	0	30100	2	60200	11.5
15	R()	3	SG	0	0	30100	5.6	168560	32.4
16	B()	1	CF	0	0	91510	.16	14641	2.8
TOTALS						278783	1.8	519693	

IW	INSULATED WALL
UAS	UNINSULATED ASBESTOS
HCC	HOLLOW CONCRETE BLOCK
SG	SINGLE GLAZING
CAL	CLADDING/ASBESTOS LINER
CB	CAVITY BRICKWORK
UAS/SG	UAS/SG COMB
U56	U VALUE 5.6
U.6	U VALUE .6
UB	UNINSULATED BASE
IAS	INSULATED ASBESTOS
CF	CONCRETE FLOOR
INSR	INSULATED ROOF
COMPR	COMPOSITE ROOF

VENTILATION DATA

VOL	A/C	LOAD
2791055	2.5	2325879

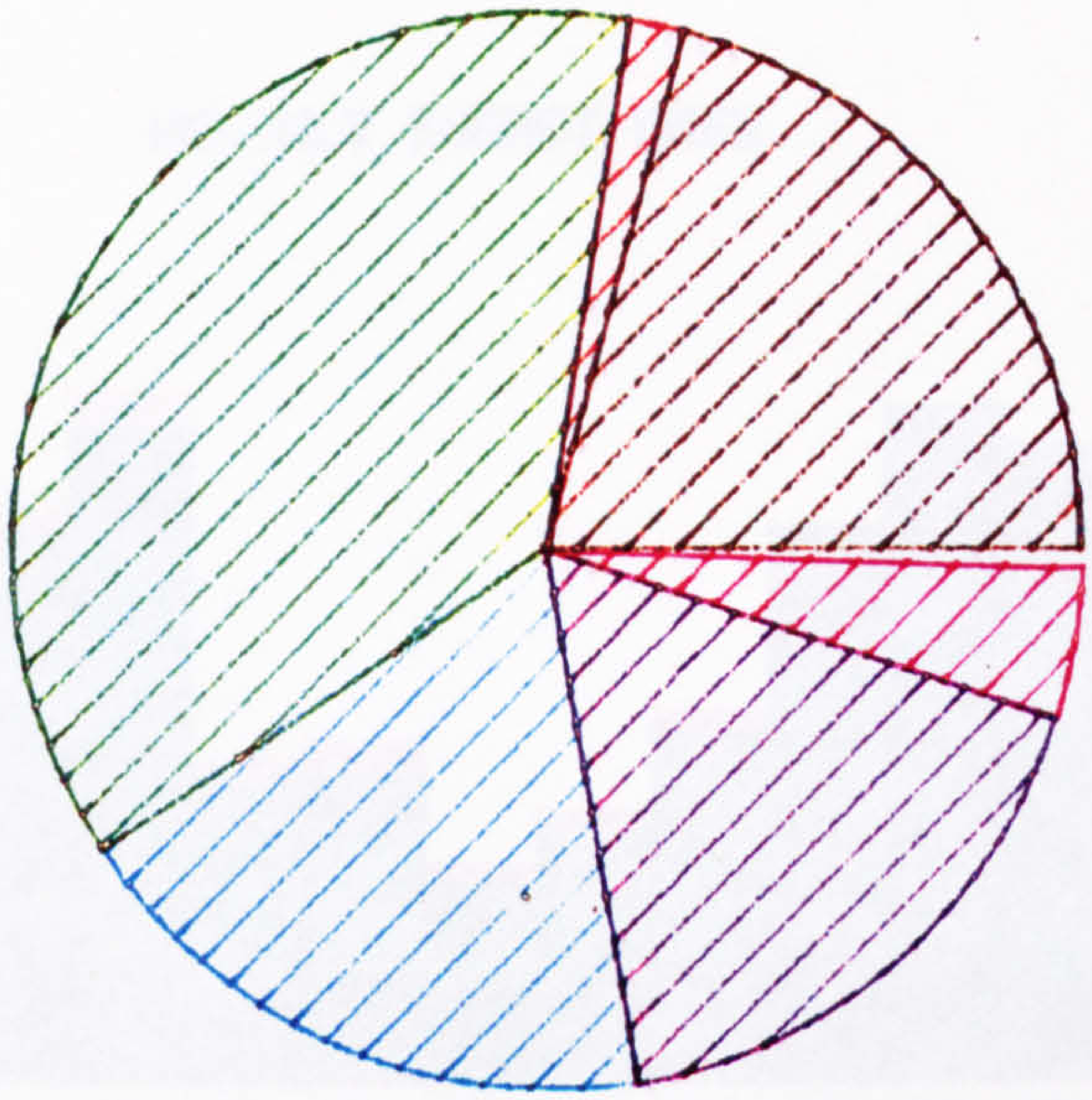
TOTAL LOAD W/DEG 2845572

FABRIC/VENT RATIO .2

Fig.4.1

		ANNUAL ENERGY			
		USAGE		COST	
ENERGY TYPE	COLOUR	KWH	%	POUNDS	%
ELEC		1.25X10^ 8	20	4.36X10^ 6	44
ELEC/CAIR		1.07X10^ 7	1	3.71X10^ 5	3
PROGASINT		2.21X10^ 8	36	2.27X10^ 6	23
HTGASINT		1.1X10^ 8	18	1.18X10^ 6	12
FIRMGAS		1.04X10^ 8	17	1.14X10^ 6	11
STEAM		2.76X10^ 7	4	4.32X10^ 5	4
TOTAL		5.99X10^ 8		9.75X10^ 6	

USAGE



COST

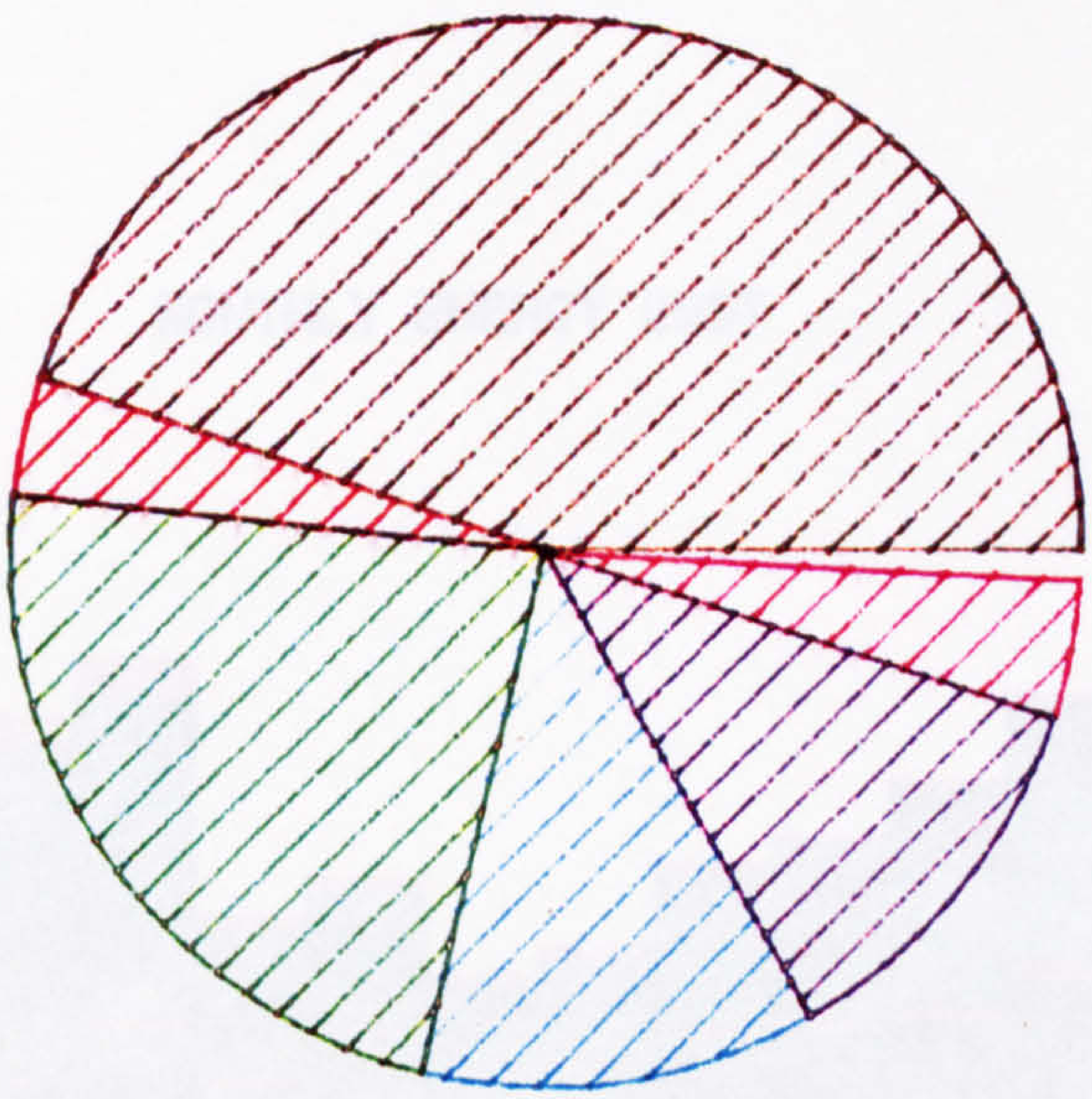
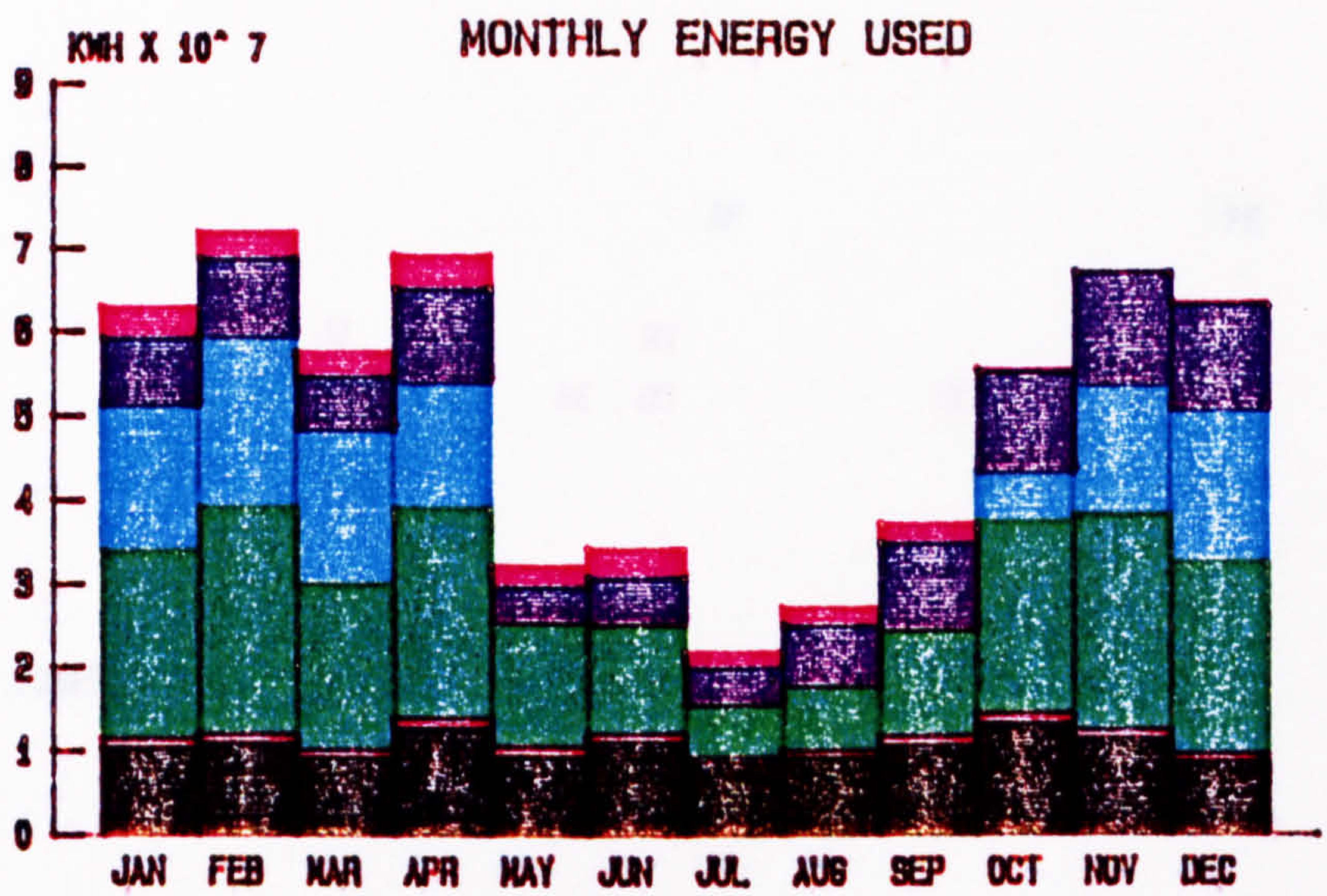


Fig.4.2

	ENERGY TYPE										COLOUR		
	ELEC												
	ELEC/CAIR												
	PROGASINT												
	HIGASINT												
	FIRMGAS												
	STEAM												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
ENERGY KWH X 10^ 7	6.27	7.18	5.74	6.89	3.2	3.41	2.17	2.7	3.71	5.54	6.7	6.33	59.91
COST POUNDS X 10^ 5	11.93	13.38	9.13	10.1	5.69	6.35	4.66	5.19	6.57	7.07	7.95	9.46	97.54



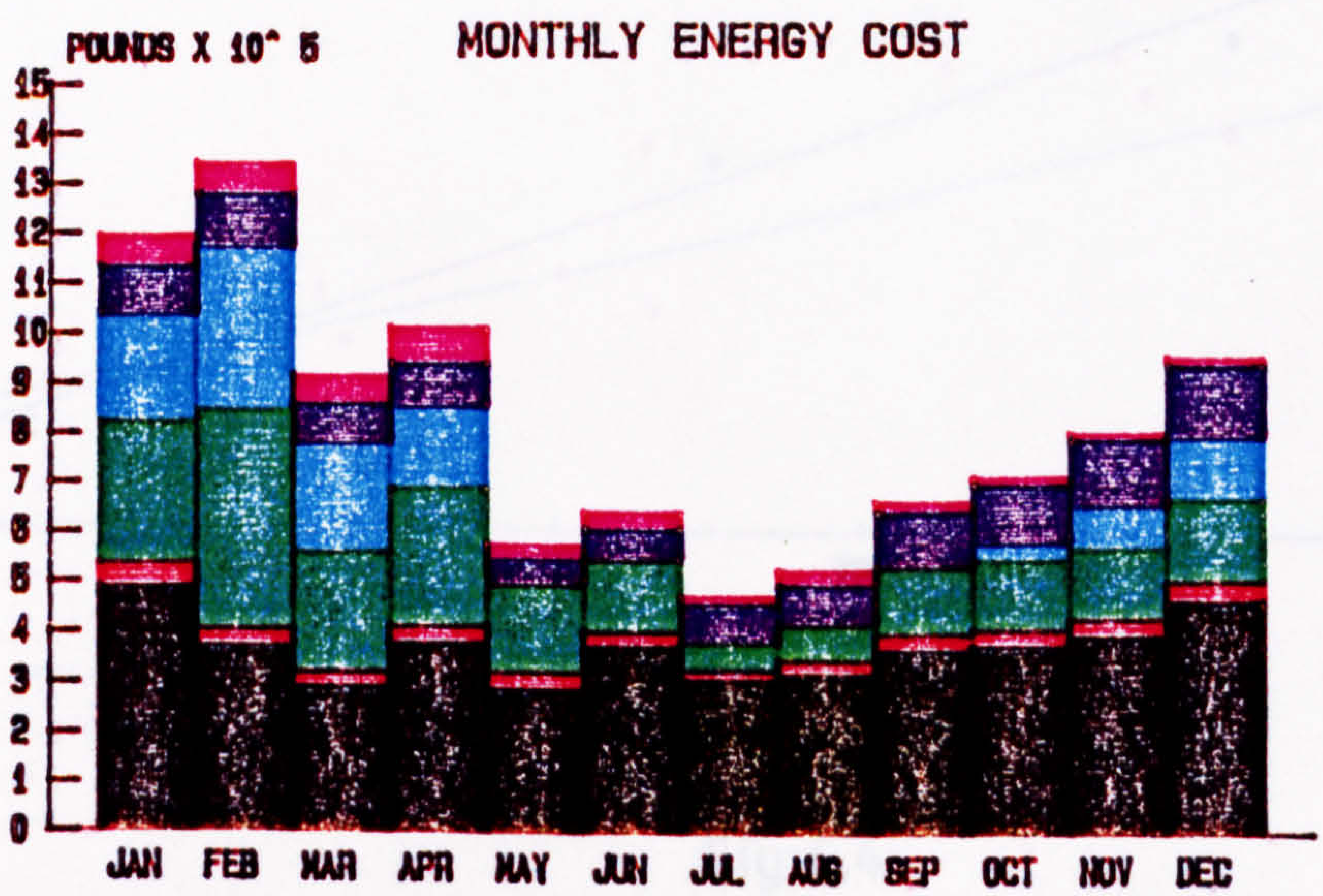


Fig.4.3

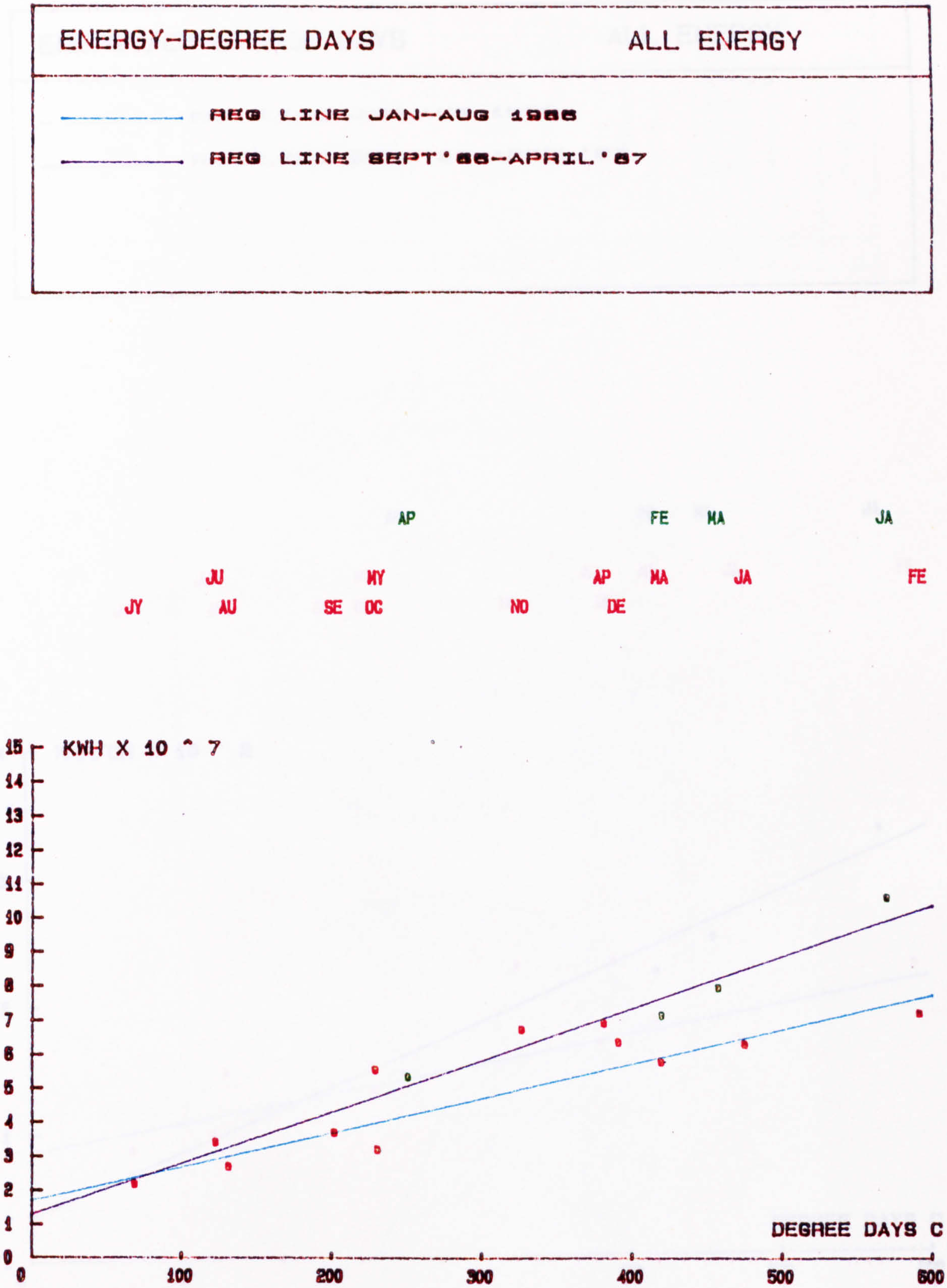

ENERGY-DEGREE DAYS
ALL ENERGY
REG LINE JAN-AUG 1986
REG LINE SEPT'86-APRIL'87
AP
FE
MA
JA
JU
MY
AP
MA
JA
FE
JY
AU
SE
OC
NO
DE
KWH X 10 ^ 7
DEGREE DAYS C
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
100
200
300
400
500
600

Fig. 4.4

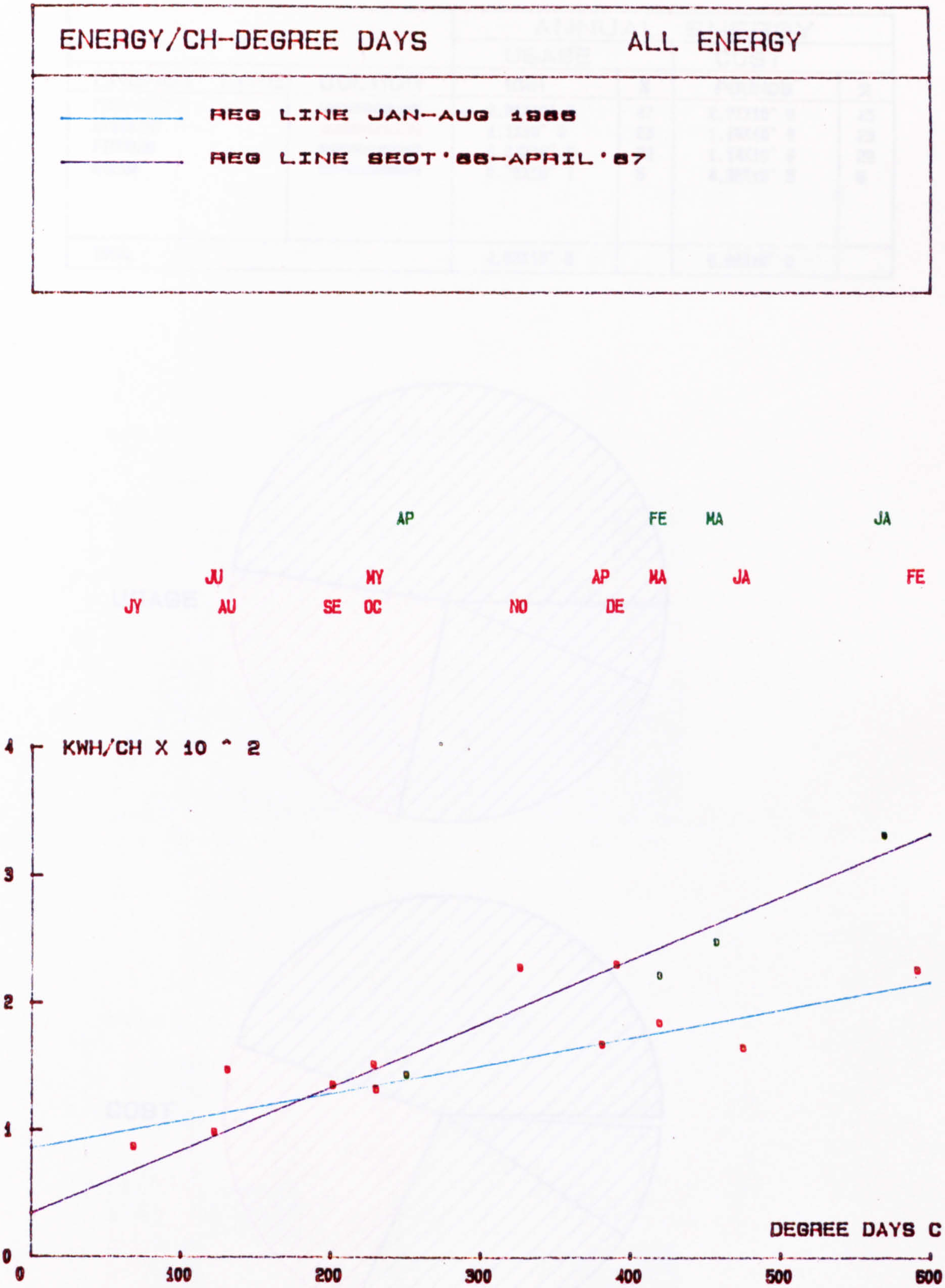
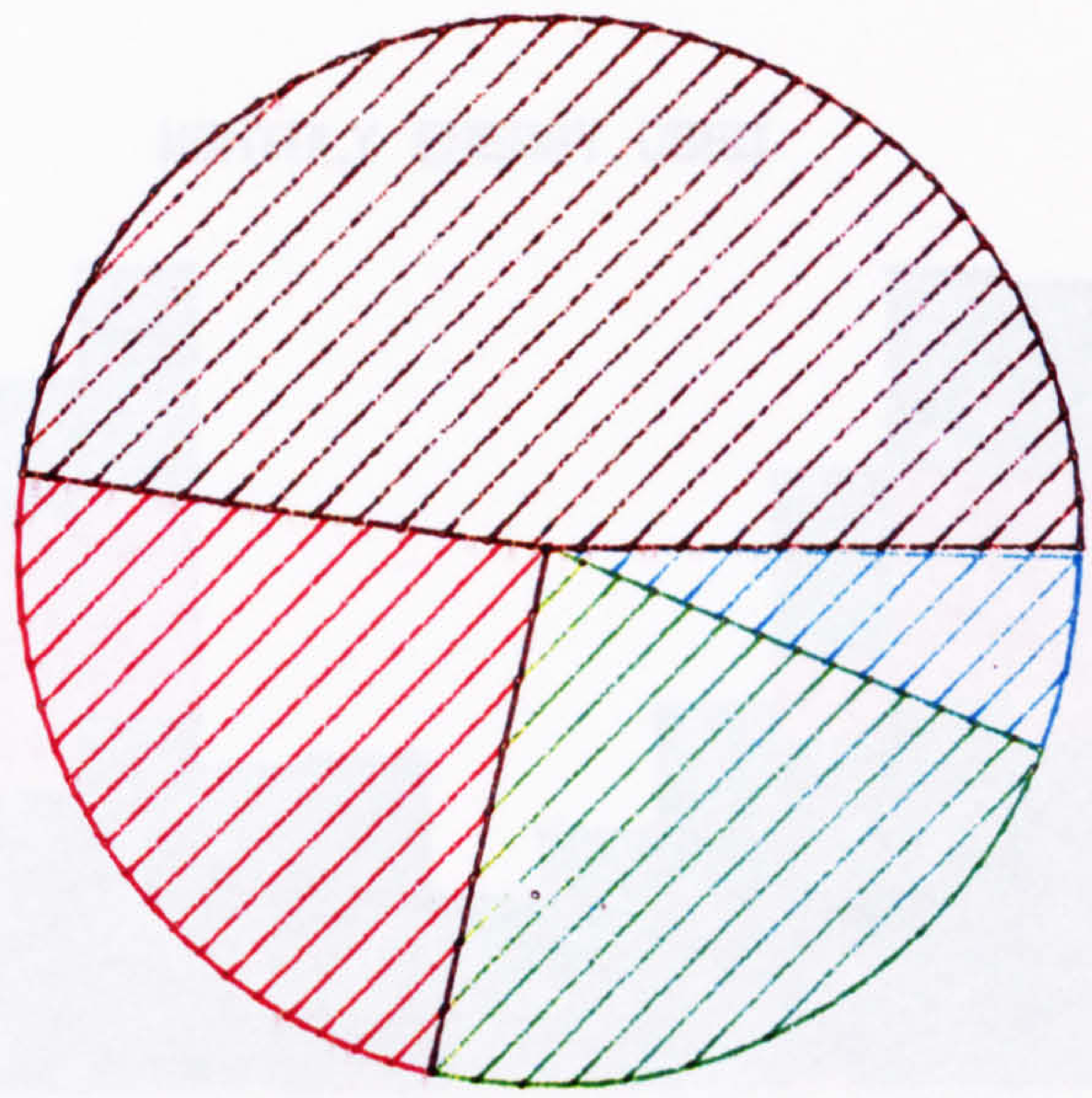

ENERGY/CH-DEGREE DAYS
ALL ENERGY
REG LINE JAN-AUG 1986
REG LINE SEOT'86-APRIL'87
AP
FE
MA
JA
JU
MY
AP
MA
JA
FE
JY
AU
SE
OC
NO
DE
KWH/CH X 10 ^ 2
DEGREE DAYS C
0
1
2
3
4
0
100
200
300
400
500
600

Fig.4.5

		ANNUAL ENERGY			
		USAGE		COST	
ENERGY TYPE	COLOUR	KWH	%	POUNDS	%
PROGASINT		2.21X10^ 8	47	2.27X10^ 6	45
HTGASINT		1.1X10^ 8	23	1.18X10^ 6	23
FIRMGAS		1.04X10^ 8	22	1.14X10^ 6	22
STEAM		2.76X10^ 7	5	4.32X10^ 5	8
TOTAL		4.63X10^ 8		5.02X10^ 6	

USAGE



COST

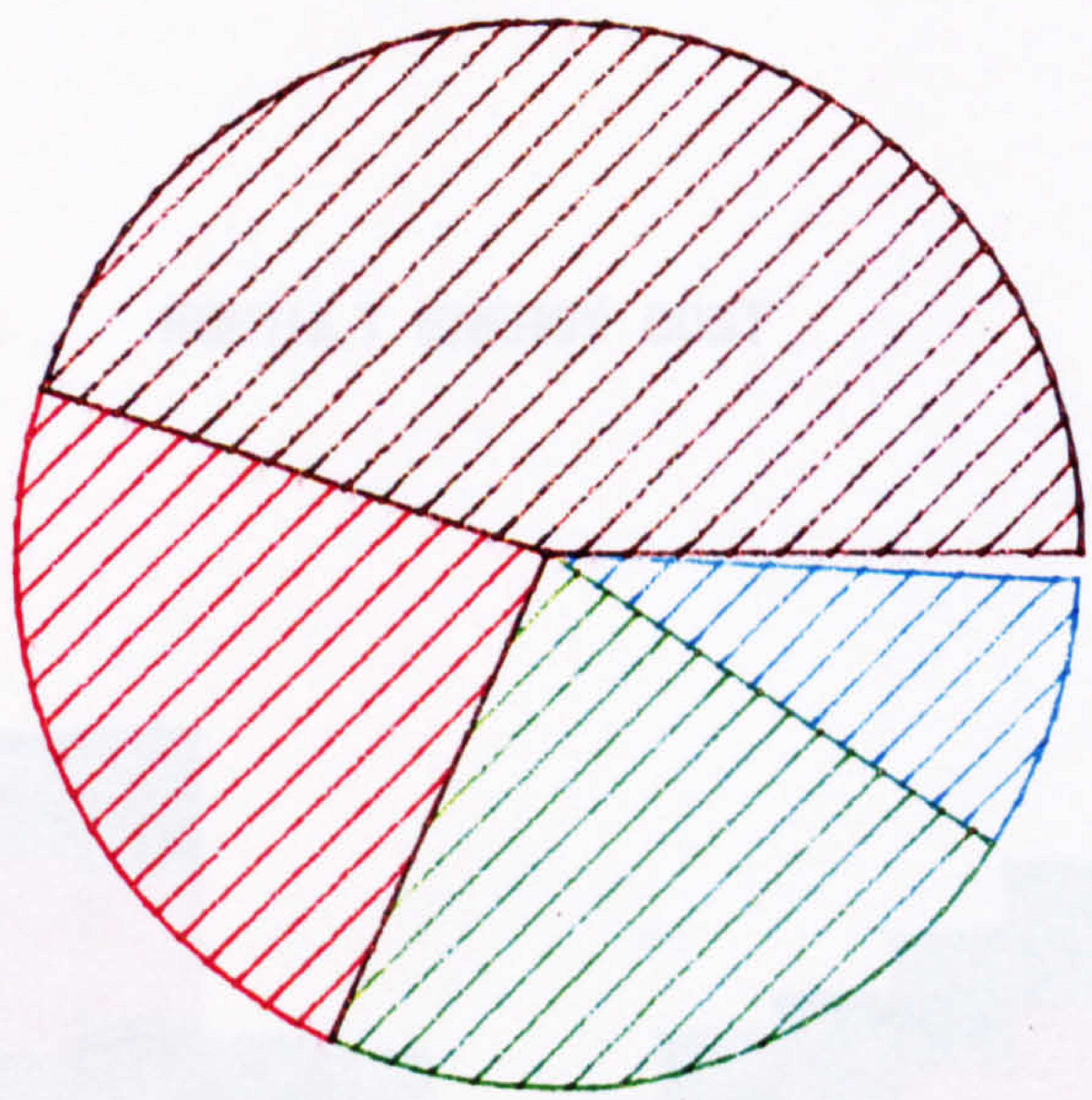
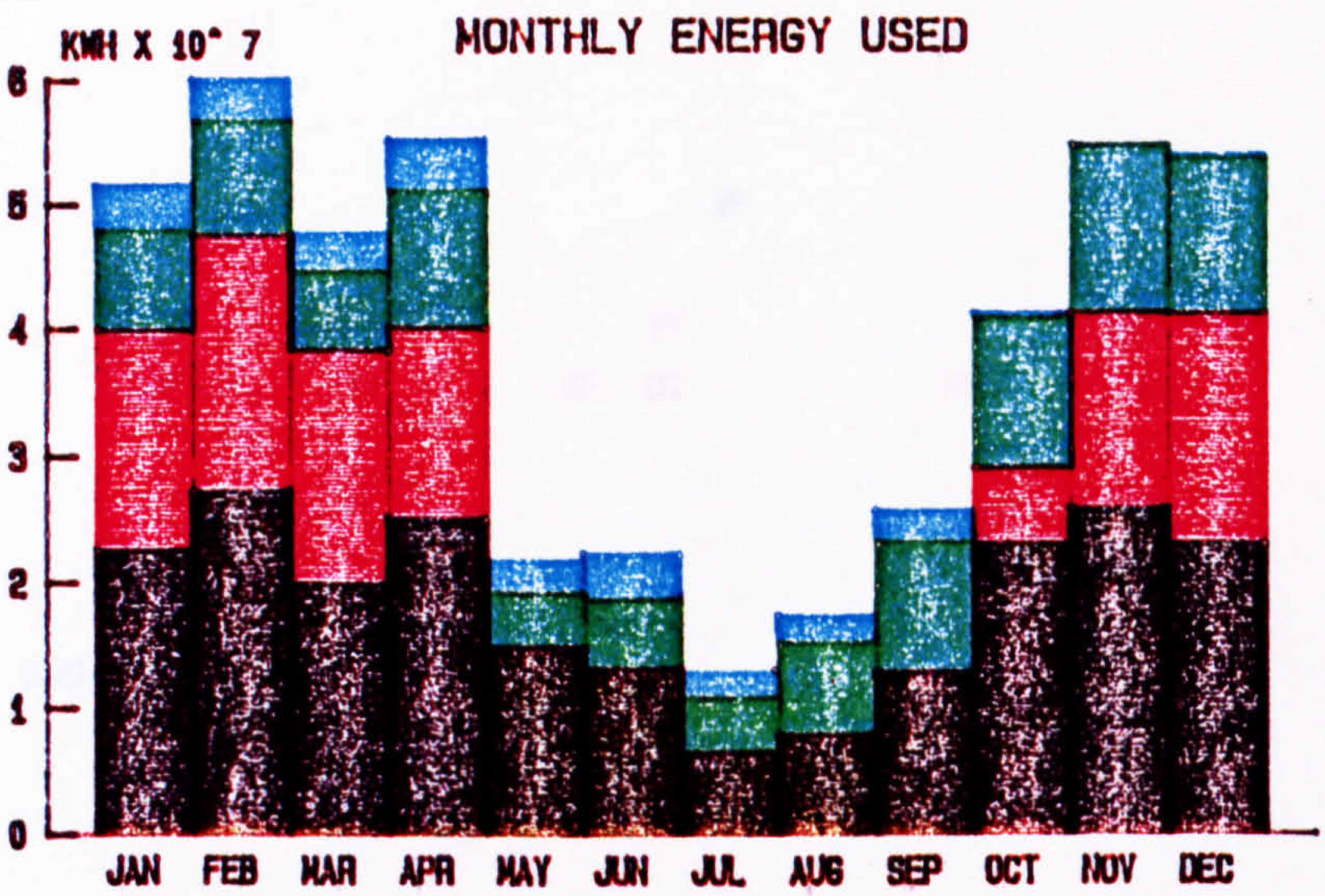


Fig.4.6

ENERGY TYPE	COLOUR
PROBASINT	(black)
HTGASINT	(red)
FIRMGAS	(green)
STEAM	(blue)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
ENERGY KWH X 10^ 7	5.14	5.99	4.75	5.51	2.16	2.22	1.27	1.72	2.55	4.11	5.47	5.38	46.33
COST POUNDS X 10^ 5	6.61	9.36	5.97	6.03	2.55	2.39	1.47	1.81	2.64	3.07	3.74	4.51	50.2



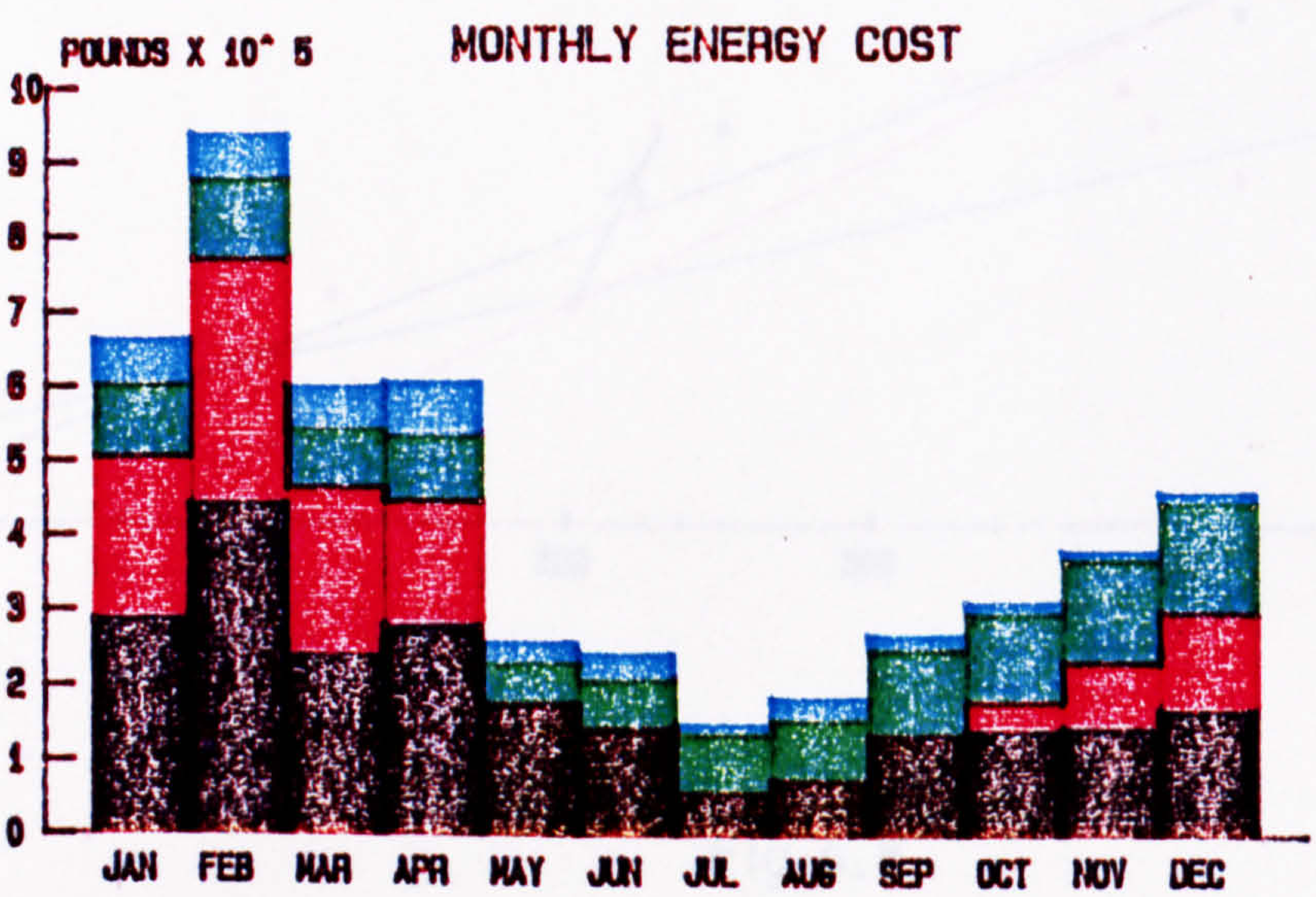
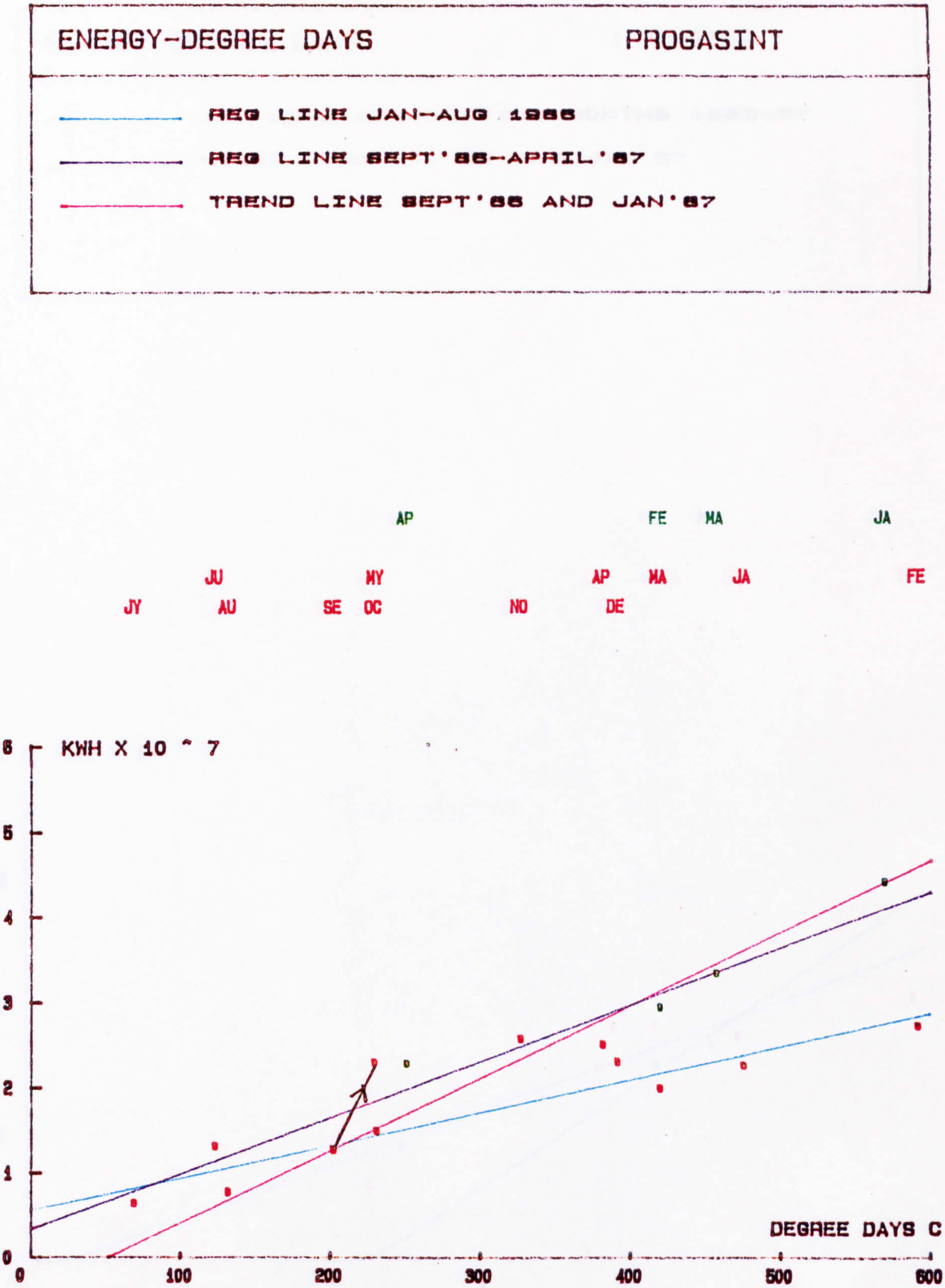
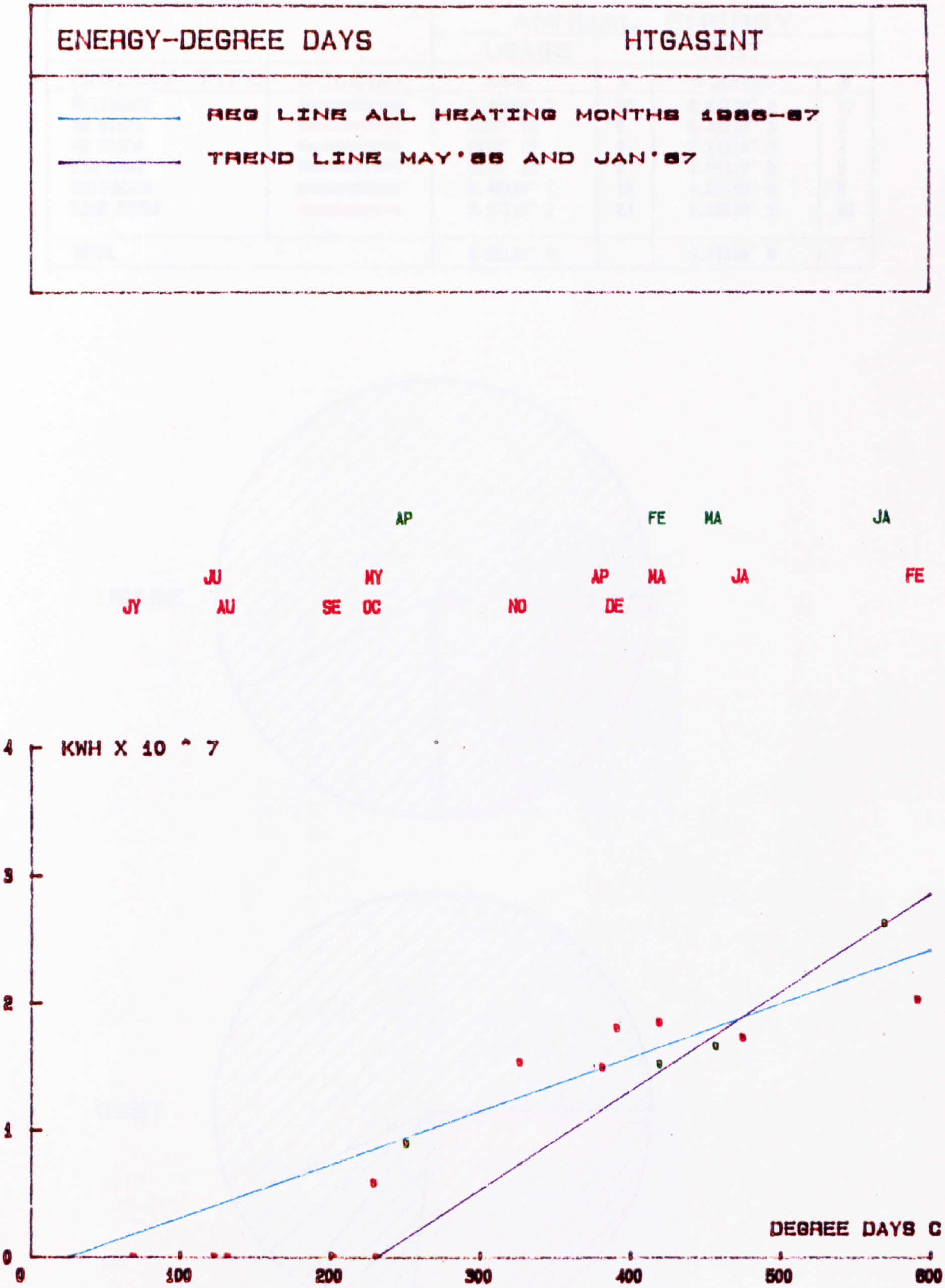


Fig.4.7



ENERGY-DEGREE DAYS
PROGASINT
REG LINE JAN-AUG 1986
REG LINE SEPT'86-APRIL'87
TREND LINE SEPT'86 AND JAN'87
AP
FE
MA
JA
JU
MY
AP
MA
JA
FE
JY
AU
SE
OC
NO
DE
KWH X 10 ^ 7
DEGREE DAYS C
0
1
2
3
4
5
6
100
200
300
400
500
600

Fig. 4.8

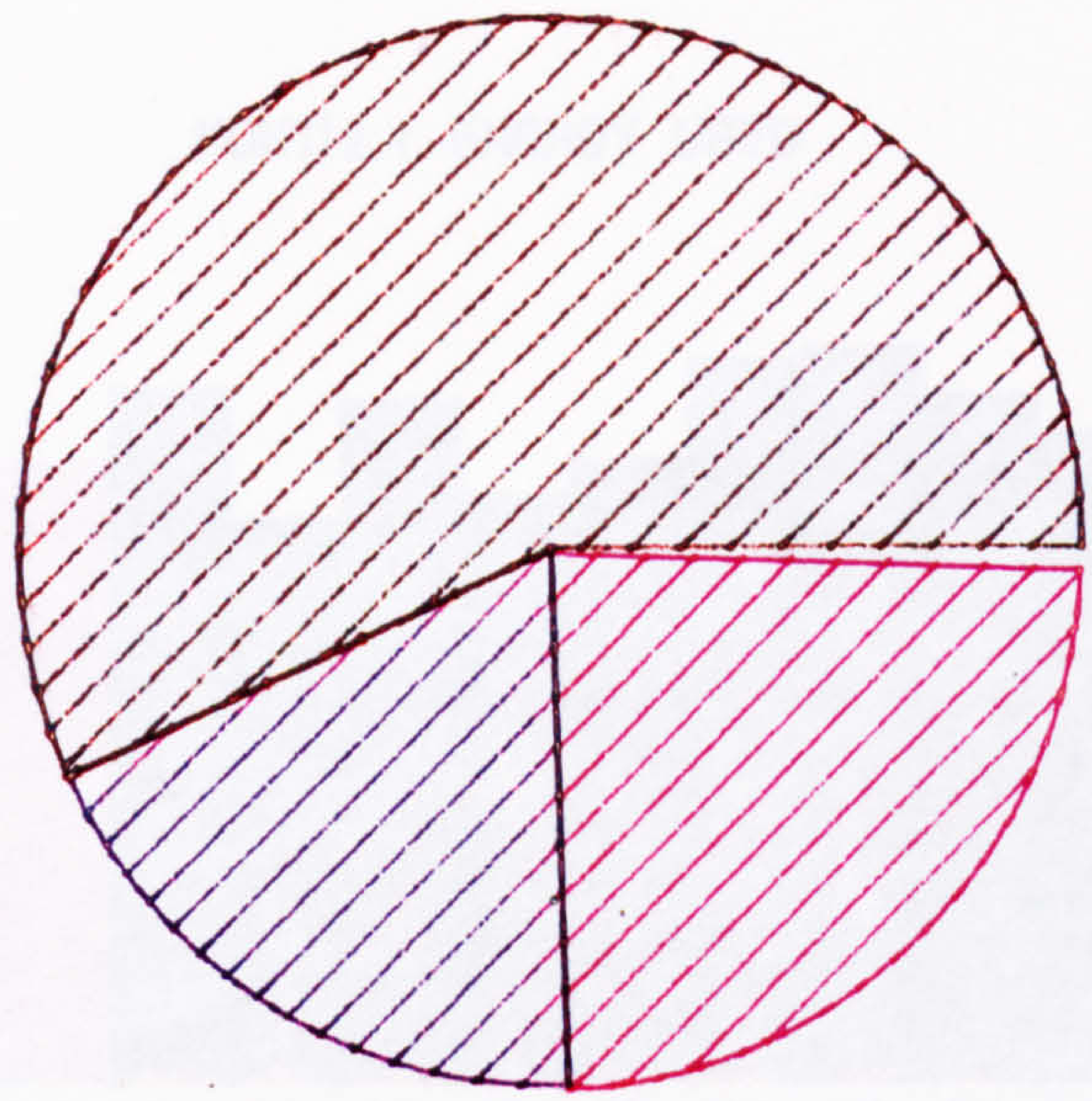


ENERGY-DEGREE DAYS
HTGASINT
REG LINE ALL HEATING MONTHS 1986-87
TREND LINE MAY'86 AND JAN'87
AP
FE
MA
JA
JU
MY
AP
MA
JA
FE
JY
AU
SE
OC
NO
DE
KWH X 10 ^ 7
4
3
2
1
0
DEGREE DAYS C
0
100
200
300
400
500
600

Fig.4.9

		ANNUAL ENERGY			
		USAGE		COST	
ENERGY TYPE	COLOUR	KWH	%	POUNDS	%
UNITCHAR1		7.48X10^ 7	56	2.69X10^ 6	57
MD STEP1		0X10^ 13	0	2.43X10^ 3	0
MD STEP2		0X10^ 13	0	2.14X10^ 5	4
FIX CHAR		0X10^ 13	0	1.66X10^ 5	3
UNITCHAR2		2.48X10^ 7	18	4.09X10^ 5	8
LOAD MANAG		3.17X10^ 7	24	1.23X10^ 6	26
TOTAL		1.31X10^ 8		4.71X10^ 6	

USAGE



COST

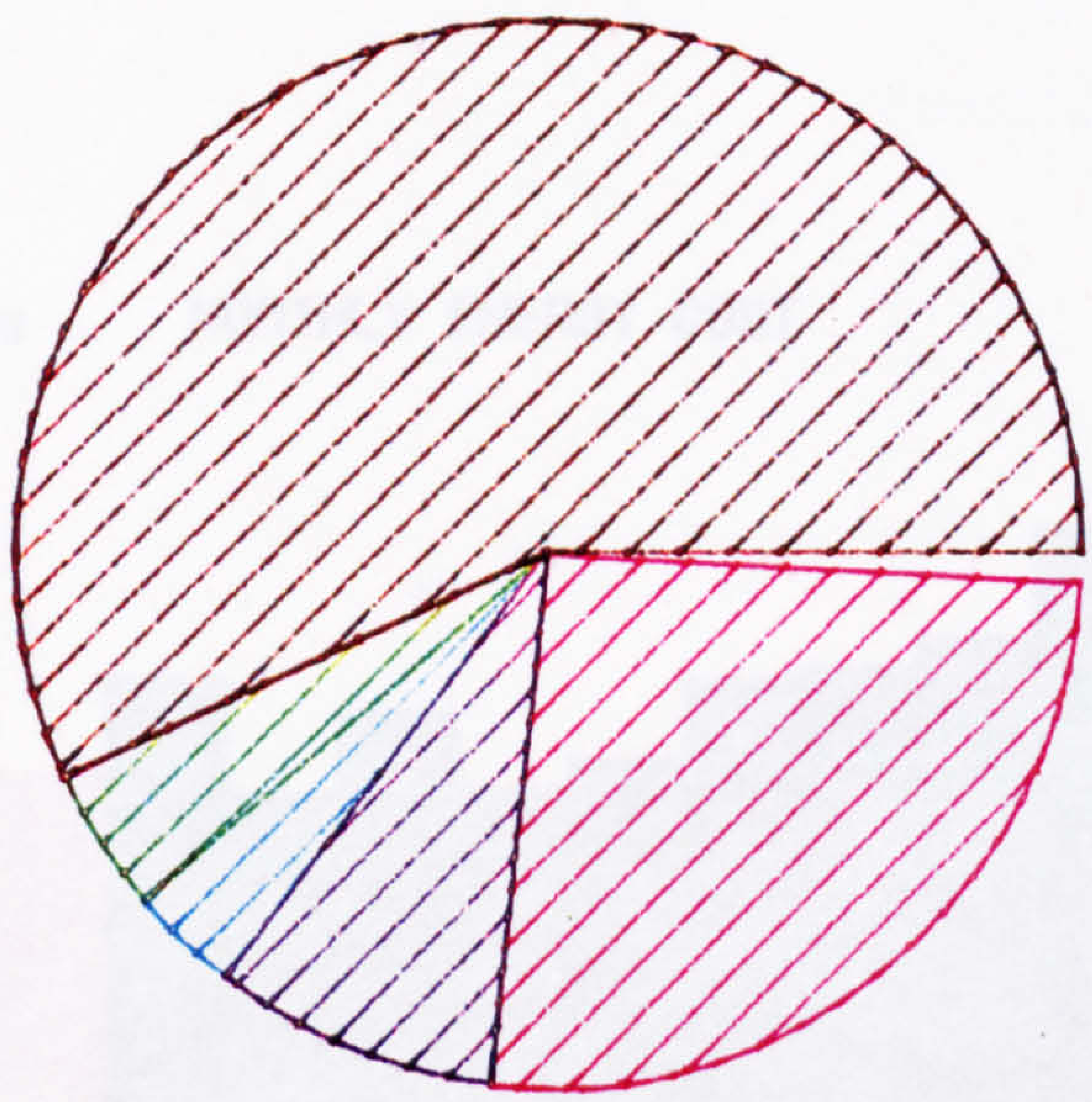
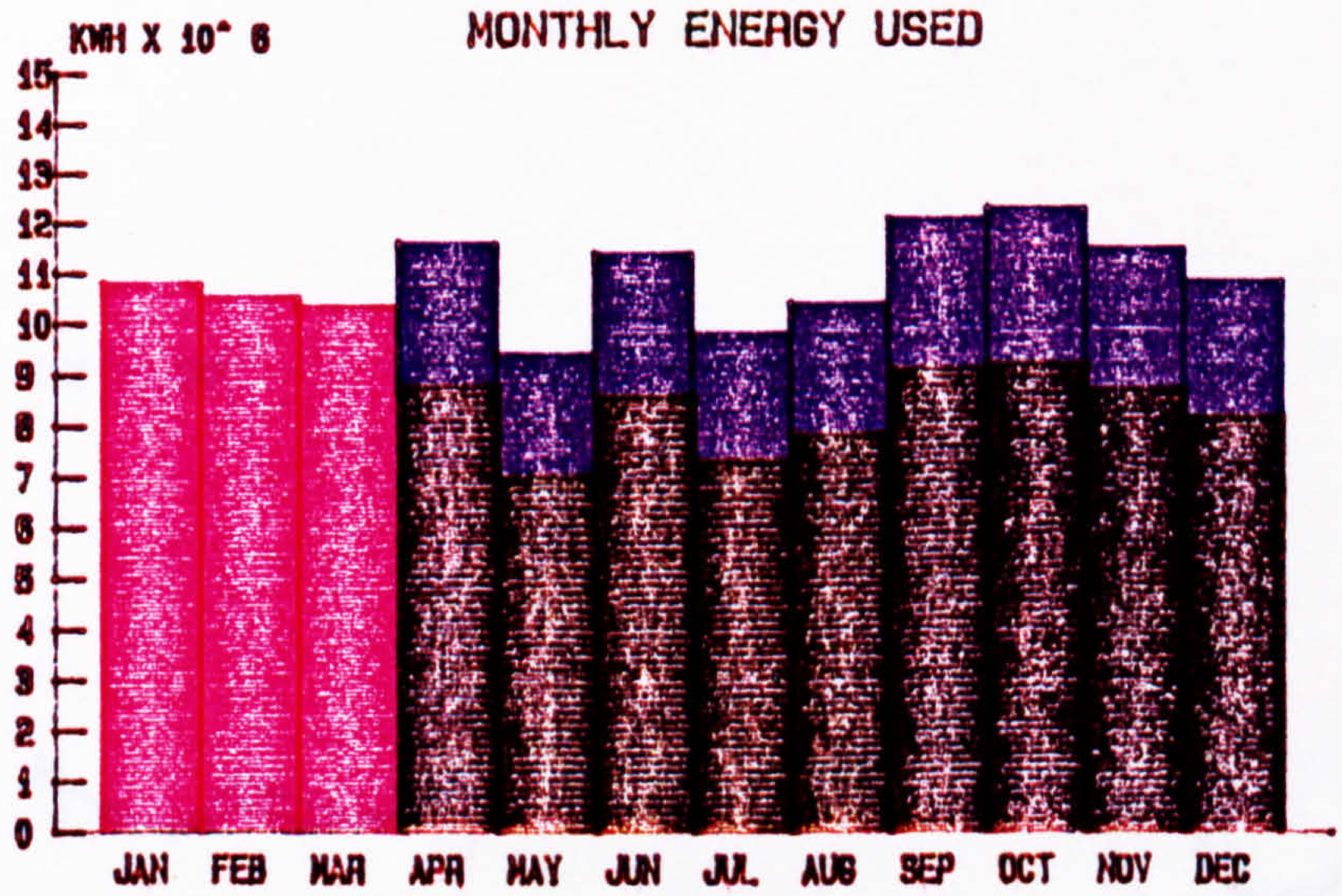


Fig.4.10

ENERGY TYPE	COLOUR
UNITCHAR1	
MD STEP1	
MD STEP2	
FIX CHAR	
UNITCHAR2	
LOAD MANAG	

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
ENERGY KWH X 10^ 6	10.81	10.54	10.36	11.62	9.44	11.42	9.85	10.42	12.12	12.34	11.52	10.87	131.36
COST POUNDS X 10^ 5	5.32	4.01	3.28	3.94	3.14	3.7	3.19	3.38	3.93	4	4.21	4.94	47.08



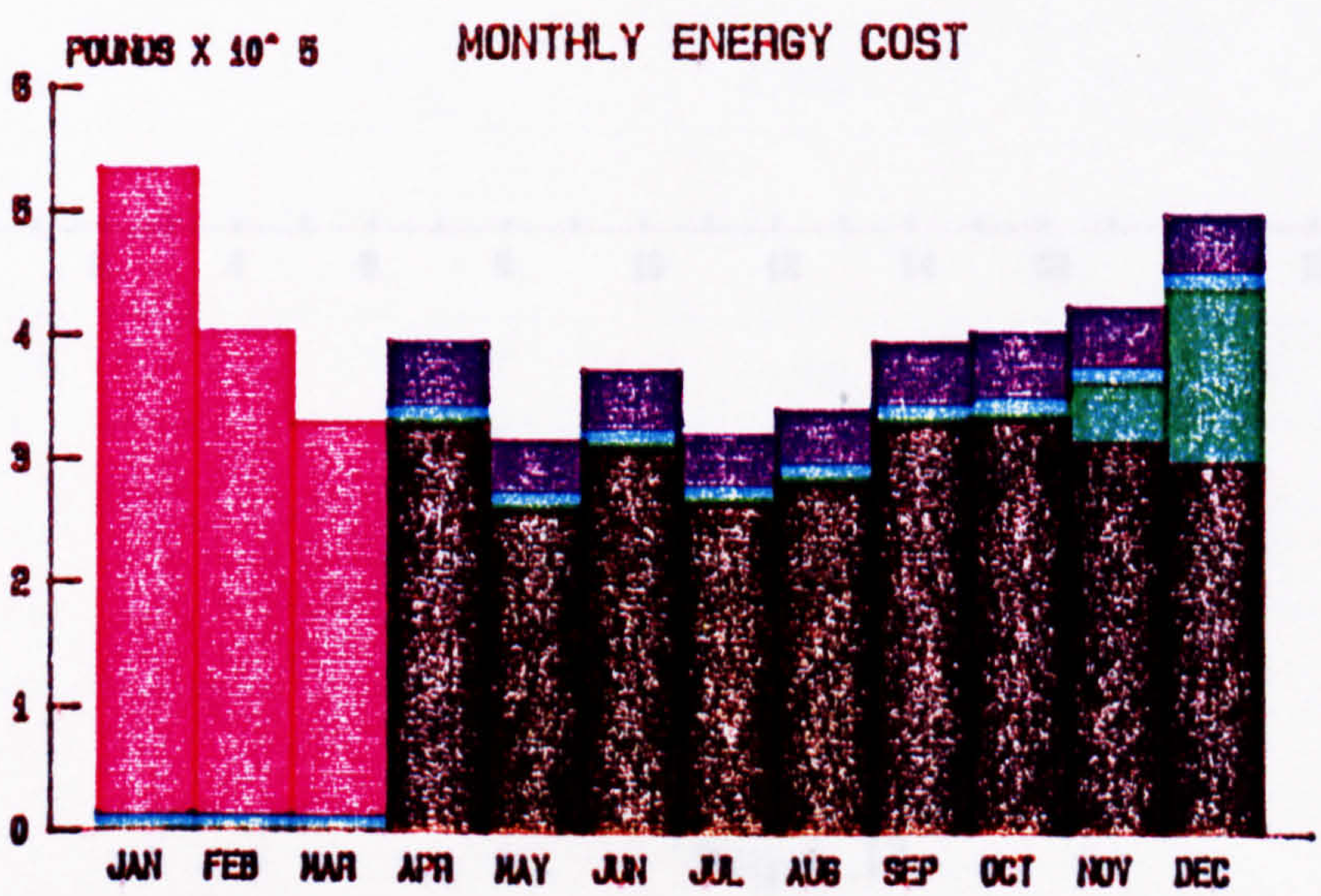


Fig.4.11

DAILY POWER VARIATION 13/12-19/12 1986

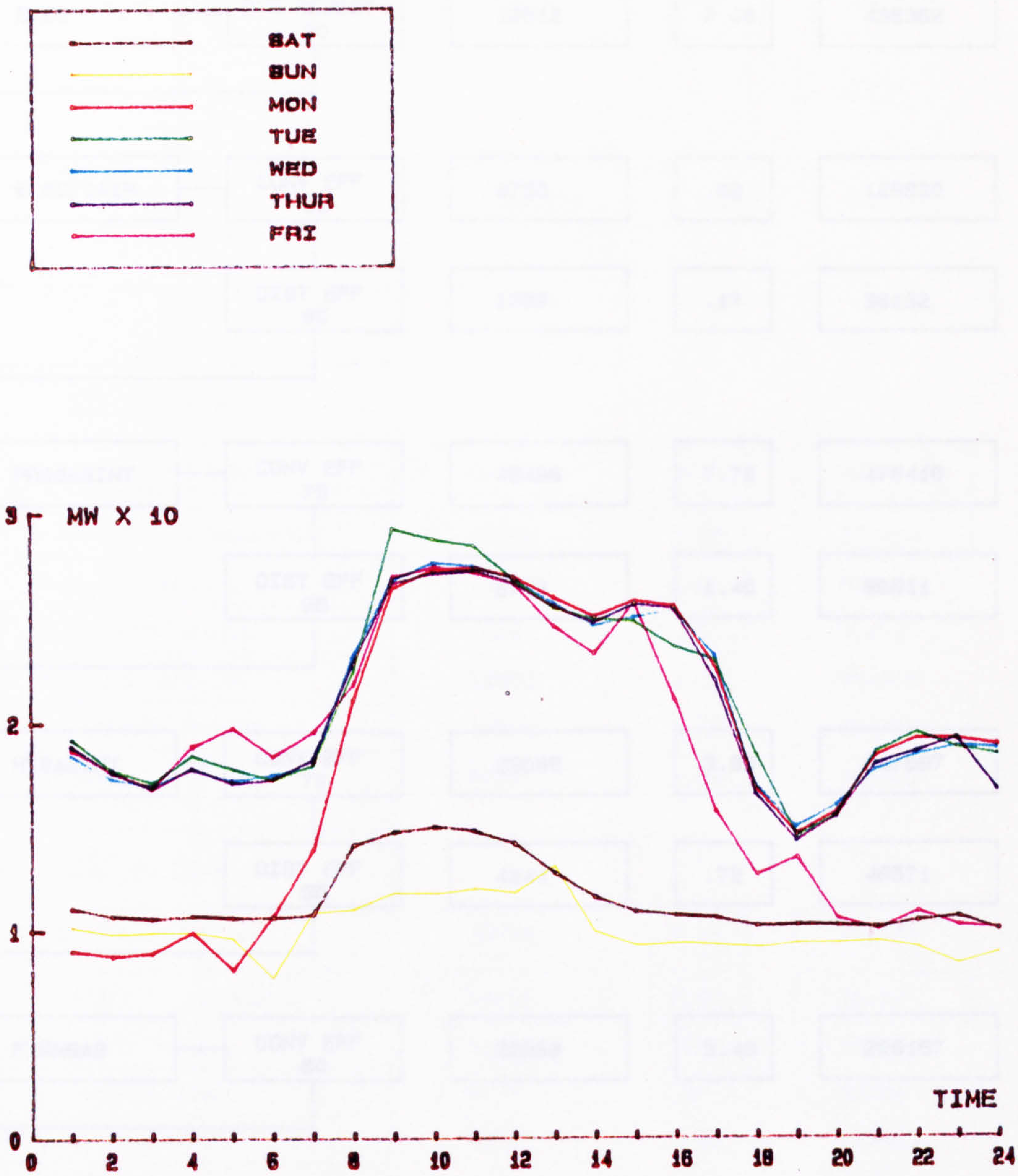


Fig. 4 .12

		ENERGY LOSS MW-HR	% TOT	COST POUNDS	% TOT
ELEC	DIR REJECT 90	12512	2.08	436362	4.47
ELEC/CAIR	CONV EFF 65	3733	.62	129920	1.33
	DIST EFF 85	1039	.17	36192	.37
PROGASINT	CONV EFF 79	46498	7.76	476416	4.88
	DIST EFF 95	8746	1.45	89611	.91
HTGASINT	CONV EFF 79	23096	3.85	247597	2.53
	DIST EFF 95	4344	.72	46571	.47
FIRMGAS	CONV EFF 80	20863	3.48	228167	2.33
STEAM	CONV EFF 60	11053	1.84	172625	1.76
	DIST EFF 90	1657	.27	25893	.26

Energy audit plot
Fig. 4.13 (i)

	ENERGY LOSS MW-HR	% TOT	COST POUNDS	% TOT
RESIDUAL	24421	4.07	412570	4.22
TOTAL ENERGY TO BUILDINGS	441175	73.63	7452983	76.4
AC BLOCK				
VENTILATION	232403	38.78	3926093	40.24
FABRIC LOSSES	51928	8.66	877244	8.99
SOLID WALL	13247	2.21	223790	2.29
GLAZED WALL	1656	.27	27979	.28
SOLID ROOF	13906	2.32	234936	2.4
GLAZED ROOF	16842	2.81	284529	2.91
BASE	6275	1.04	106009	1.08
AA BLOCK				
VENTILATION	56535	9.43	955078	9.79
FABRIC LOSSES	15862	2.64	267977	2.74
SOLID WALL	1112	.18	18793	.19
GLAZED WALL	2177	.36	36780	.37
SOLID ROOF	7320	1.22	123663	1.26
GLAZED ROOF	4140	.69	69950	.71
BASE	1112	.18	18788	.19

Fig.4.13(ii)

	ENERGY LOSS MW-HR	% TOT	COST POUNDS	% TOT
AH BLOCK				
VENTILATION	3636	.6	61428	.62
FABRIC LOSSES	6291	1.05	106279	1.08
SOLID WALL	1056	.17	17840	.18
GLAZED WALL	512	.08	8655	.08
SOLID ROOF	684	.11	11562	.11
GLAZED ROOF	3832	.63	64751	.66
BASE	205	.03	3468	.03
VX BLOCK				
VENTILATION	8386	1.39	141677	1.45
FABRIC LOSSES	16791	2.8	283667	2.9
SOLID WALL	213	.03	3611	.03
GLAZED WALL	5130	.85	86674	.88
SOLID ROOF	5241	.87	88544	.9
GLAZED ROOF	5870	.97	99169	1.01
BASE	335	.05	5667	.05
P BLOCK				
VENTILATION	10291	1.71	173884	1.78
FABRIC LOSSES	6725	1.12	113617	1.16
SOLID WALL	366	.06	6191	.06
GLAZED WALL	2396	.39	40478	.41
SOLID ROOF	885	.14	14962	.15
GLAZED ROOF	2912	.48	49201	.5
BASE	164	.02	2781	.02

Fig.4.13 (iii)

	ENERGY LOSS MW-HR	% TOT	COST POUNDS	% TOT
J BLOCK				
VENTILATION	2081	.34	35166	.36
FABRIC LOSSES	763	.12	12904	.13
SOLID WALL	322	.05	5443	.05
GLAZED WALL	251	.04	4253	.04
SOLID ROOF	149	.02	2532	.02
GLAZED ROOF	0	0	0	0
BASE	39	0	675	0
W BLOCK				
VENTILATION	2843	.47	48029	.49
FABRIC LOSSES	5096	.85	86101	.88
SOLID WALL	522	.08	8833	.09
GLAZED WALL	467	.07	7893	.08
SOLID ROOF	917	.15	15504	.15
GLAZED ROOF	3018	.5	50988	.52
BASE	170	.02	2881	.02
K BLOCK				
VENTILATION	10031	1.67	169468	1.73
FABRIC LOSSES	11506	1.92	194383	1.99
SOLID WALL	1340	.22	22646	.23
GLAZED WALL	0	0	0	0
SOLID ROOF	2271	.37	38378	.39
GLAZED ROOF	7471	1.24	126223	1.29
BASE	422	.07	7135	.07

Fig.4.13(iv)

CHAPTER 5

DETAILED ANALYSIS MONITORING

5.1 Introduction.

The approach taken for the general analysis, as described in chapter three, is justified in that it enables some energy saving opportunities, as discussed in chapter four, to be easily identified. Given the input data for the year, the output data is quickly generated using a P.C. (personal computer). Since the hardware employed is often commonplace in industry, the process is also quite cheap. Furthermore, because the interpretation of the data requires only a minimum of plant knowledge such as the annual heating period etc., such an analysis may be performed remotely with input data being transferred by modem and the PSTN (Public switched telephone network). Hence, it may be carried out by a central bureau which monitors data for several plants on a running monthly basis.

A tour of the plant may reveal opportunities for energy conservation which have not been specifically identified by the general analysis. At the plant studied, this immediately revealed several areas of energy waste: the over illumination of buildings; windows left open in heated buildings; excessive space temperatures; over-running ventilation plant and numerous compressed air losses from leaking hoses and connectors. Such wastage is easily identified and rectified.

The general analysis and the plant tour offer, between them, considerable scope for energy savings which should be remedied immediately. Apart from these obvious deficiencies in energy conservation, it is apparent that other latent ones frequently occur. Specifically, the concern here is to identify ways of saving energy by operating plant as efficiently as possible within the constraints of the existing plant. In order to do this, the energy consumption must be monitored together with other parameters which may affect that consumption. One may then attempt to determine the functional dependence of the energy consumption on those parameters for a particular item of plant. This approach is often called Monitoring and targeting (M and T), mentioned in section 2.8, and differs from the general analysis and the plant tour in several ways viz: it must be performed over an extended period of weeks or months; it requires transducers, wiring, installation, monitoring and logging equipment which may prove costly and it requires plant knowledge.

This chapter describes a real time monitoring system which was developed for the boilerhouse which supplies the whole plant with HPHW for process and space heating requirements. Past experience indicates that, for most industrial plants, the single most effective way to cut energy costs is by increasing the overall efficiency of the boilerhouse (Trim, 1984). Apart from this general observation, it was decided to consider the boilerhouse for several reasons viz:

(1) the HPHW boilers consume more than 50% of the total annual energy usage of the plant at a cost of 3.45 million pounds;
(2) supervisory staff in the boilerhouse were of the opinion that procedures for optimising the efficiency of HPHW production were open to improvement;
(3) no centralised monitoring system for boiler performance existed;
(4) preliminary investigations indicated discrepancies in the existing instrumentation;
(5) the energy audit (section 4.8) indicated that a small increase in average annual operating efficiency would produce significant savings.

5.2 The Boilerhouse.

The boilerhouse houses five LaMont water tube contraflow boilers, each originally rated at 70 million BTU/hr (British thermal units per hour) but since uprated to 80 million BTU/hr. They supply high pressure hot water (HPHW) at 180 - 190 p.s.i. and 180 C to heating and process headers via a ring main. Return water temperatures vary but temperature differentials are typically between 15 and 40 C. The boilers are fed with natural gas and, on occasion when this supply is interrupted, with heating oil. A general view of the boilerhouse firing floor is shown in photograph 5.2(i). Combustion air is taken from the top of the boilerhouse and from ducting around the boiler to the FD (forced draught) fan situated beneath each boiler which blows the air into the boiler from below - hence the air is pre-heated (see photograph 5.2(ii)). The working pressure of the HPHW system is maintained by nitrogen cylinders discharging into a pressure vessel. Water circulation is maintained by eleven centrifugal pumps, each rated at between 1150 and 2200 g.p.m. (gallons per minute). The flow arrangement for the HPHW inside the boilerhouse is shown in fig. 5.1. The five boilers supply two sets of HPHW mains to the plant, process and heating, via two sets of headers. Only one set of headers is shown in the figure for simplicity. The water flows from the boilers to the pump suction headers, through the pumps to the pump discharge headers and finally to the plant mains via the process (and heating) flow headers. The water returns from the plant via the process (and heating) return headers to the boilers. A mixing valve and bypass enable cooler return water to be mixed with that which has been heated by the boilers. Recent plant additions have increased the flow demands such that it is not possible to operate a single boiler when energy demand is low because the flow rates through a single boiler cannot match those of the plant. Hence, whilst a single boiler has the capacity to provide the required power, flow limitations require that at least two boilers are on line. Consequently, it is commonplace, in summer months, for two boilers to be operating each at around 40% load. Potential efficiency improvements through modifications to the HPHW flow system within the boilerhouse have been identified, as a result of this work, and are being implemented.

5.3 Boiler Control.

Each of the five boilers is individually controlled by a Westinghouse 1500, microprocessor based, general purpose controller (GP1500), shown in photograph 5.3(i). This enables fully metered, cross limited combustion control with oxygen trim (Westinghouse, 1981(a)). A platinum resistance thermometer (PRT) measures the temperature of the water flowing from each boiler and sends this temperature to the controller. This is compared with a set point temperature (180 C) by the temperature controller and the resultant error signal generated is then sent to both the fuel and air controllers which in turn vary the fuel valve and air damper positioners respectively. Cross limiting is achieved by measuring the fuel and air flows and passing each of these signals, after scaling and offset corrections are made, to the controller for the other as well as to their own controllers. Hence, during load changes on the boiler, a rapidly changing fuel flow will immediately cause a sympathetic change in the air flow via this cross limiting mechanism and vice versa.

In addition to water flow temperature, fuel flow and air flow, other boiler parameters are measured viz: furnace pressure, flue gas temperature and flue gas oxygen concentration. The measurement of furnace pressure is used to control the ID (induced draught) damper such that the furnace pressure is kept just below ambient. The flue gas oxygen concentration is measured by a probe (photograph 5.2(ii)) containing a zirconia (zirconium oxide) cell which produces a Nernst voltage which is a function of the ratio of the oxygen concentrations on either side of the cell. By exposing one side of the cell to instrument air and the other to the flue gases and measuring the Nernst voltage under known isothermal conditions (approximately 850 C), the oxygen concentration of the flue gases is determined (Westinghouse, 1981(b)). This signal is processed and sent via a 4-20 mA loop to the oxygen controller. This signal is compared with an oxygen set point which is a function of boiler load and the local set point (i.e. manually entered) and the error signal thus generated is used to trim the position of the air damper.

The temperature of the flue gases is measured by a thermocouple in the stack and this together with the measured oxygen concentration is used by an algorithm in the GP1500 to calculate the boiler efficiency. Examination of the algorithm blockware indicated two approximations which render the displayed efficiency inaccurate. Firstly, since combustion air temperature is not measured, a constant value of 37 C is assumed in the calculation of combustion efficiency (BS, 1972; BS, 1974) and since this efficiency is a function of (flue gas temperature - combustion air temperature), this approximation will generally lead to errors. Measurements taken during summer months, indicated that this temperature was closer to 50 C. The second approximation used in the algorithm was a constant value for the percentage radiation loss. Whilst the value taken of 3% is of the correct order for a water tube boiler at its maximum continuous rating (Osborn, 1985), it is too low for a boiler on half load. Hence a second error is introduced into the displayed boiler efficiency. Attempts were made to overcome these problems for the system developed (see section 6.2.1).

5.4 Monitoring System - General.

In order to develop an M and T system for the five HPHW boilers, it was necessary to measure and log several of the parameters mentioned above and additional ones. Initial thoughts of using a separate set of transducers, including ultrasonic flowmeters for HPHW flow, linked to a monitoring system were soon discounted when the cost of equipment and installation were investigated. It was finally decided to link the existing transducers used by the GP1500 controller plus additional transducers to a dedicated monitoring system situated in the control room of the boilerhouse. The aim was to implement a complete monitoring system which would enable real time monitoring display and logging of relevant parameters such that this information could be analysed and targets of energy consumption set. The following sections describe the hardware and software development of this system.

5.5 Hardware.

5.5.1 Data Logging.

Two possible approaches to a personal computer based monitoring system are possible (Burr-Brown, 1988) and were considered. The first utilises a number of boards, with functions such as: analog input; analogue to digital conversion; signal conditioning, which plug into the expansion slots of the PC (Metrabyte, 1988). Transducer connections are then made directly to the expanded PC. The advantages of this approach are that the system is fast (although this is not a consideration here), self-contained, compact, relatively cheap and the data appears directly on the internal bus of the PC and can be accessed without the need for an interface. However, expansion capabilities are limited unless expansion modules are used. The second approach utilises a data-logger as a 'front-end' which performs the signal measurement and logging function. This is then connected via an external bus to a PC which, by using suitable software, can interrogate the data logger and transfer information into the PC. Since a suitable PC was not initially available but a data logger was, the second approach was chosen. A Fluke 2240B data logger was installed with an IEEE 488 interface card. The logger has the ability to record up to 60 channels of voltage with several ranges from 0 to 40 V available. Unfortunately, the logger could measure only voltage and limited the range of input signals which could be recorded. An Amstrad 1512 personal computer was purchased and fitted with an Advantech (AD50488) IEEE 488 bus controller card. This enabled the two way transfer of information between the PC and the data logger such that the data logger could be programmed from the PC, by switching the logger to remote, and data from the logger could be passed to the PC.

5.5.2 Boiler Data Collection.

The GP1500 controller had options for voltage and current signal outputs for the four measured boiler parameters and the derived efficiency. Whilst the current outputs appeared initially preferable because of the possibility of electrical noise affecting a voltage signal, additional cards in each controller were required which would have been very costly. The voltage option, however, could be implemented by changing jumpers in the GP1500 and modifying the blockware. This was done for each controller and by including a suitable scale block, an output voltage range of 0 - 4 V was selected to coincide with a similar range on the data logger. Data transmission quality cable consisting of nine individually screened pairs was then run from the analogue output connector block at the rear of each of the five GP1500 controllers to terminal connectors in the control room and then to the input blocks of the data logger. These cables varied in length from about 20 metres for the nearest boiler to 40 metres for the furthest.

As mentioned in section 5.3, it was necessary to measure combustion air temperature in order to calculate the combustion efficiency. A platinum resistance PT 100 thermometer (TC, 1987), length 200mm, sheath diameter 6 mm, fitted with a heavy duty head and a 3/4" BSP bush was fitted into the combustion air plenum of each boiler (photograph 5.5.2(i)). A 4-20 mA head mounting transmitter (span 0-100 deg.C) was used with each thermometer. A screened pair was then connected from the transmitter to one of the unused pairs in the nine pair cable and hence the signal was fed to the control room. Here each current loop was powered with a 24 V d.c. supply and connected in series with a 200 ohm precision resistor which converted the 4-20mA current signal into a 0.8-4 V voltage signal. The wiring arrangement for each boiler is shown in figure 5.2.

5.5.3 Environmental Data Collection.

Five environmental parameters were monitored viz: solar radiation (global); wind speed; wind direction; air temperature and relative humidity. Their details are now discussed. The wiring arrangement is shown in figure 5.3.

Solar radiation was measured with a Kipp and Zonen CM 6 pyranometer (photograph 5.5.3(i)), as this is considered a standard instrument which has performed well in the past (Ferraro, 1983). It was equipped with an adjustable base and screen and mounted horizontally on a wooden stand (which could be adjusted to enable measurement on a south-facing inclined plane if necessary) on the roof of the boilerhouse. The sensitivity of this instrument, about 11.5 microvolts per watt per sq.m, means that the signal is only of the order of millivolts. Amplification was considered but the high input impedance of the data logger enabled the signal to be transmitted without any signal conditioning despite the use of a 50 metre connection cable.

Wind speed and direction were measured by a Munro IM 146 in line wind speed and direction unit installed on a 20 ft. mast on top of the tallest building on the plant. A cup anemometer is mounted axially above a wind direction vane to form the in line transmitter, both being manufactured to Meteorological Office standards (photograph 5.5.3(ii)). The cup of the anemometer is fixed on a spindle connected to a 6 pole rotor which turns inside a stator generating an a.c. voltage which varies in frequency with the speed of rotation. A 7 core cable was used to provide a 50 V a.c. supply to the wind vane transmitter and carry the speed and direction signal back to a Munro digital wind display unit (1A/614) situated on the firing floor in the boilerhouse (photograph 5.5.3(iii)). This unit provides an LED display of wind speed in a variety of units and wind direction as a bearing. The figures displayed for both speed and direction may be selected to represent 2 second, 2 minute or 10 minute averages. The unit was installed with a 4-20 mA analogue output for both speed and direction and screened cables were taken about 60 metres from these outputs to the data logger where the voltage drop across a 200 ohm precision resistor was measured for each of the two current loops.

Ambient air temperature and relative humidity were measured by a Vaisala HMD 20Y combined temperature and humidity unit (photograph 5.5.3(iv)). This is comprised of a 'Humicap' capacitative humidity sensor (commonly used in weather stations) and a PT 100 platinum resistance thermometer each connected to a 4-20 mA transmitter. The unit was situated inside a Stevenson screen on the roof of the boilerhouse and two screened cable pairs were brought down into the control room. Each sensor was then wired in a current loop in series with a 24 V d.c. supply and a 200 ohm resistor.

5.5.4 Plant Data Collection

Whilst both the boiler data and the environmental data could be returned to the monitoring system using hardwired connections with maximum cabling runs of about 60m, this was not possible for data collection from factory blocks which would involve cable runs of several hundreds of metres. The cabling costs and the installation time required would have been outside the scope of the work.

This difficulty was overcome by using a low power radio telemetry data acquisition system (Bell, 1987) which was originally developed for process plant monitoring in oil refineries. The system may be used over ranges up to 5 km depending on the choice of antennae and local conditions and operates at a frequency of about 173 MHz. In its most general form, the system comprises of a central master station and up to a large number of 'slaves' which are distributed around the site and interfaced to sensors or actuators. The master sends an address word to each slave in turn to initiate data transfer and the data is stored by the master until it initiates further communication when the data is updated. The period between scans may be chosen to suit the application. A schematic diagram of the system used in this work is shown in fig. 5.4. A slave was wall-mounted in one of the factory blocks as shown in photograph 5.5.4 (i) with the capability of accepting data from eight thermocouple channels (type K) and eight current loop channels. Six of the eight thermocouple channels were connected to patch thermocouples which measured the surface temperature of 14" and 16" hot-water mains into the factory block (photograph 5.5.4(ii)). The remaining two thermocouple channels were connected to two air probe thermocouples which measured the internal air temperature within the block. The slave was powered from a 240 V supply and connected to an end fed dipole antenna mounted on top of the roof. An antenna on top the roof of the boilerhouse was connected to the master station which was in turn connected to the monitoring computer via an RS232 cable. A view of the monitoring system in its final configuration which employed an IBM XT personal computer and a Solatron Orion data logger is shown in photograph 5.5.4(iii).

5.6 Software - Preliminary Considerations.

The Advantech IEEE 488 interface, used in the PC, has software held in ROM (read only memory) which enables GPIB (General purpose interface bus) commands to be implemented from the main program. Each GPIB command (e.g. output, device, etc.) is issued by a call to one of a number of assembly language subroutines held in ROM and all data is transferred between the main program and the interface in string form (Advantech, 1987). This protocol requires that the programming language used for the main program is compatible with IBM Basic A or GW Basic. Furthermore, it was decided that a compiled language would be used, rather than an interpreted one, such that a self contained program could be developed which could be executed directly from MS DOS (Microsoft Disk Operating System). Borland TurboBasic (Borland, 1987) was initially chosen as it purported to be Basic A compatible. This was not the case as the call absolute statement used to invoke an assembly language subroutine in this language enabled only integers to be passed and not strings. Microsoft QuickBasic Version 3 (Microsoft, 1987(a)) was then obtained and found suitable in this and other respects and was subsequently used to develop the software. Since the software needed to log and display data in real time it was initially thought that the use of Microsoft Windows (Microsoft, 1987(b)) would be a suitable environment. This provides an extension to DOS by allowing multiple programs to be run simultaneously using a time slicing technique. However, since the PC used did not have hard disc storage, it was found that the time overheads incurred accessing files on floppy disc when using Windows were such that the execution times of programs were considerably lengthened. Consequently, this approach was abandoned and a single program was used with the monitoring function being implemented by a background interrupt driven routine.

5.7 Software - Program BOILER.

The program developed to log and display all the measured data in real time (named BOILER) is now briefly described. It was developed and then compiled into an executable file using the QuickBasic compiler and libraries. A program listing is given in appendix B.

5.7.1 Overview.

The program is made interactive through the use of a menu system. When the program is run, the user is confronted with a main menu, shown in figure 5.5, with options selected by entering various letters. Some of these options carry out certain tasks whilst others lead to further menus and so on. At any point in the program, the user may end the program, return to the main menu or return to the previous menu by pressing the keys 1, 2, and 3 respectively. A display at the bottom of the screen may be switched on (see fig. 5.7) which defines the functions of these keys (the keys 4 to 10 are not used). In this way, the user may move around in the program, displaying menus, data or program status information as they wish. The program may be used to log data, display currently logged data and display previously logged (filed) data. The logging function is controlled by a timer driven interrupt. Alternatively, if the logging function is not initiated, the program may be used simply to peruse filed data. An option to exit to DOS (the disc operating system) between monitoring scans was included in order to copy data files from the hard disc to floppy disc without interrupting the program. The Status listing in fig 5.5 indicates that logging is on, that the data file BR16021.dat (16th February) is loaded into memory for examination and that data files for eight days have been stored to disc since logging was last commenced. The program may be considered as two main modules, log and trend which are responsible for the background data logging and the display of data in graphical form respectively.

5.7.2 Logging Data.

The logging module (log) controls the transfer of information to and from the data logger over the GPIB bus. Logging may be initiated to start immediately or at a particular time of day. Logging specifications (e.g. number of readings to be taken before filing data, time between readings, number of channels etc.) may be examined and/or changed by choosing the Examine / Change Current settings option from the main menu, leading to the display shown in fig 5.6. The logging period may be defined as single or multiple with a specified number of readings for each channel logged. A further option exists enabling data to be filed just before midnight and a new logging sequence to be initiated at midnight for 24 hours, filed and so on. This option enables logging to be carried out continuously with each day's data being separately filed, without operator intervention. The only limitation, of course, is that sufficient disk space is available for filing the data. This option is the one generally used for continuous logging.

Before logging is started, the GPIB interface is initialised and the data logger programmed with the relevant information (e.g. number of channels to be scanned, the voltage range of each channel, scan interval etc.). The RS232 serial link between the PC and the radio telemetry master station is also initialised. The communication parameters (baud rate 4800, no parity, 8 data bits, 2 stop bits) are set and the link is then tested by sending the ENQ (ascii 5) character to the master. The program waits until a NAK (ascii 21) character is returned which indicates that the PC - master link is ready for communication.

The Basic ON TIMER (SI), GOSUB ... statement is used to generate an interrupt to the program every SI seconds which transfers program control to the data acquisition subroutine which, in turn, initiates a measurement scan by the data logger. The channel data is returned in string format with each string containing 4 channel readings. Each string is sliced into four and the resulting data is converted to numerical form and allocated to a two dimensional data array element specified by the channel and reading numbers. The instantaneous boiler efficiency for each boiler is then evaluated and stored.

The data acquisition subroutine also sends a command to the radio telemetry master station which requests data for a specified number of channels and includes a check-sum. On receiving the command, the master performs its own check sum calculation and compares this with the check sum received from the PC. If they agree, the master replies with an ACK character (ascii 6) and the PC is then sent a string of data. As a further check, this string is only accepted by the PC if it begins with an SOH character (ascii 1). In this case, the string is sliced into blocks of channel data and each block is converted from hexadecimal to decimal. Finally each channel of data from the master is allocated to the data array mentioned in the above paragraph. Control is then returned from the data acquisition sub-routine to the main program.

Program status gives information concerning: logging on or off; name of filed data currently loaded; time logging started; current time; current reading number; time logging will end; scan interval; total number of readings to be taken and the name and the time of the next file to be stored. The program has an internal calendar and data files are identified by the date and a file number.

5.7.3 Data Processing.

No data processing is carried out by the logger - it transfers data as voltage readings (mostly 0-4 V) directly to the PC. The data is identified by its channel number in the program where scaling and offset are applied to convert the voltage to a reading in engineering units. Other processing such as the calculation of boiler efficiency which employs the data from several channels is performed each time a scan is made and the calculated parameter stored in an array.

5.7.4 Basic Data Display.

The trend module controls the display of data which is divided here into basic data and derived data. Basic data is that which is directly monitored by any one sensor and is then displayed, where the only data processing performed is offset and scaling. On the other hand, derived data, discussed in section 5.7.5 involves more data processing. The Display Current Data option leads to a menu, shown in figure 5.7, from which the user can choose basic data relating to an individual boiler; plant data and the weather. Individual boiler data leads to another menu from which the user may select: efficiency; fuel flow; etc. (see figure 5.8) and then finally to the actual display of the chosen parameter which plots the parameter against time. When the parameter is chosen from the menu, its channel number is identified, the necessary scaling and offset constants are allocated (which vary for each parameter) as well as other constants used for drawing the axes. The data is then displayed and the program waits until the user changes the display or another scan is taken in which case the display is updated. The user may return to the previous menu and view other parameters for the same boiler or go back two menus and view data on another boiler or weather etc. or return to the main menu. The other basic data menus, weather data (see fig.5.9) and plant data work similarly.

5.7.5 Derived Data Display

The Display Current Data menu provides the option of displaying data for All Boilers and the first of these is Total Fuel (and outside temperature).

The Total Fuel display is derived basically from the individual boiler fuel channels. However, whilst the orifice plate flowmeter which measured the gas flow to each boiler was generally accurate when the boiler was on, owing to a fault which, not uncommonly, developed on the P/I (Pressure/Current) converter, the flowmeters for some boilers indicated non-zero rates of flow when the boilers were off. Hence, the total flow could not be obtained from a simple sum of the flow readings for the individual boilers, unless all of the boilers were on which was often not the case. This problem was overcome, in the software, by using the value of the excess oxygen concentration in the flue gas to indicate if the boiler was on or off. When the boiler is on, the excess oxygen concentration in the flue gas is typically less than 5% and when the boiler is off it is in excess of 20%. To calculate the total flow, the value of the excess oxygen for each boiler was deduced from the appropriate data channel. If this was less than 15%, then the fuel flow indicated by the associated fuel channel was added to the total flow - if the value of the excess oxygen concentration was greater than 15%, then the boiler was considered off and the indicated fuel flow value ignored. The instantaneous fuel flow for all boilers is measured and displayed in SCF/hour whilst the total fuel used is found by finding the area under the graph from the trapezium rule and then converting into therms using the calorific value of the gas. The outside temperature is also plotted on the display as a dotted line. The indication to the program user that a boiler is on is provided by a thick line which runs parallel to the time axis and is numbered from 1 to 5 (since there are five boilers). Again, the value of the excess oxygen concentration in the flue gas is used as an indicator and when this value is less than 15%, the boiler is on and the boiler on line is present - when the boiler is turned off, the line disappears.

The Total Cost display available from the All Boilers menu reproduces the total fuel display and additionally displays the instantaneous cost of fuel consumption in pounds per hour using the fuel price. Again a total figure is calculated. Furthermore, the average, lowest and highest temperatures reached since midnight are also shown.

The Overall Efficiency display calculates the instantaneous mean weighted efficiency of all the boilers on line by summing the product of calculated efficiency and fuel flow for each boiler that is on and dividing by the total fuel flow, found as previously mentioned. Outside temperature is also plotted as a dotted line.

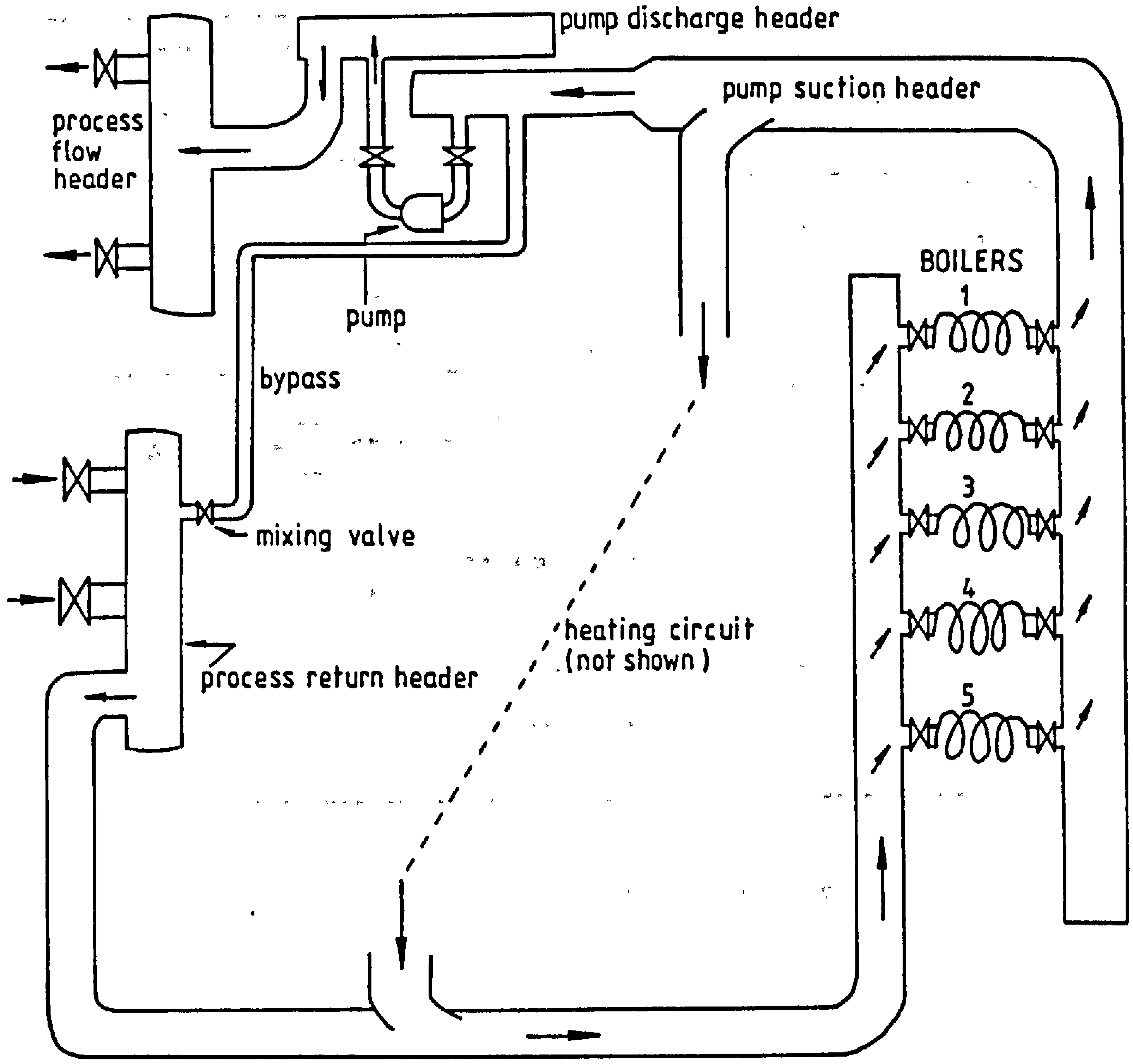
It should be noted that the individual boiler efficiency was directly input from the GP1500 controller for each boiler and is hence considered as basic data and included in section 5.7.5. However, this figure was inaccurate, owing to the approximations mentioned earlier and the actual individual efficiency figure for each boiler was evaluated by an algorithm within the program which utilised the values of excess oxygen concentration, flue gas temperature, combustion air temperature and fuel flow (to calculate the percentage radiation loss). This efficiency figure is derived data.

5.7.6 Filed Data Display

If the Display Filed Data option is chosen, the user can then list the various daily files of data previously logged and stored and load one of them. The data is transferred into a filed data array and may be examined in the same way as for the current data, as described above. Current and filed data may be displayed alternately. Different filed data may be displayed by using the exchange filed data option. Finally a hardcopy of graphical displays may be produced using a dot-matrix printer.

5.8 Communications

The monitoring PC was installed with an Amstrad MC2400 modem card which was connected to a dedicated telephone line. Using communications software (Softklone, 1987), an automatic answering program was run in the background whilst the monitoring program BOILER ran in the foreground. By calling the monitoring PC over the PSTN (Public Switched Telephone Network) from a remote PC, similarly equipped with a modem and communications software and running a file transfer program, files of previously logged data could be selected and transferred over the PSTN to the remote PC. The transfer time for a complete data file at 9600 baud was between 3 and 5 minutes.



HPHW flow circuit.

Fig. 5.1

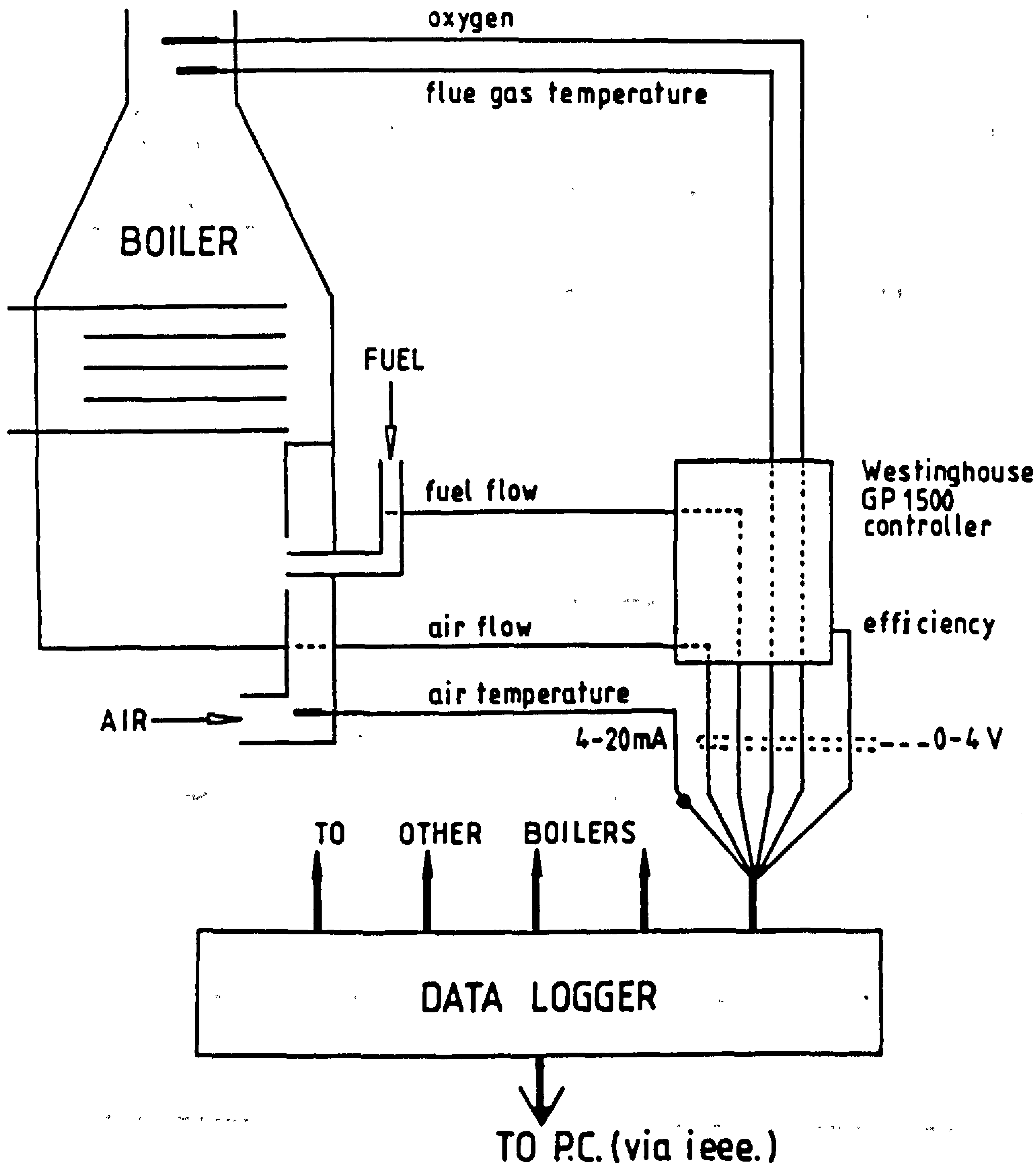


Diagram showing the boiler parameters monitored, their sensors and signal types.

Fig.5.2

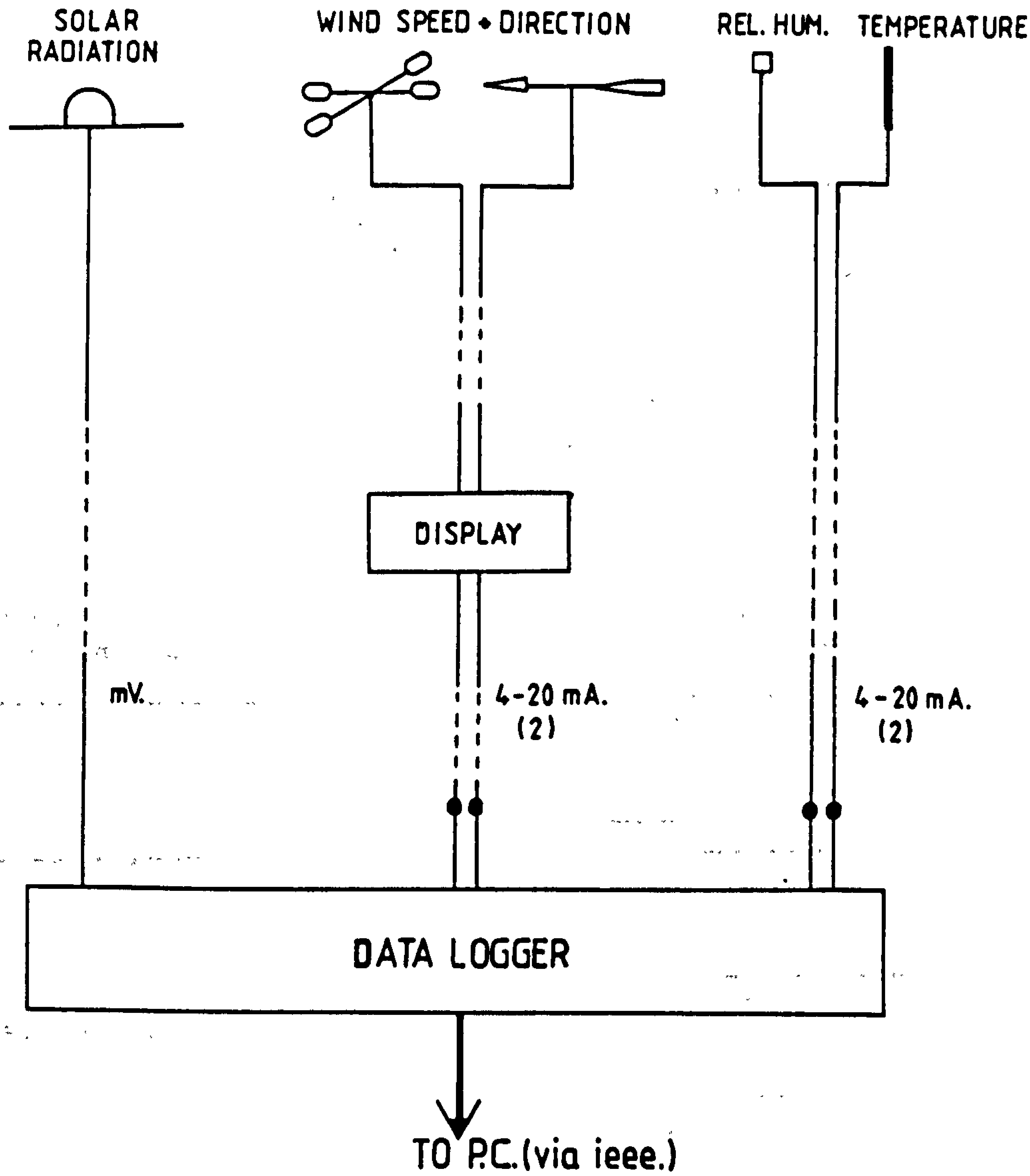


Diagram showing the environmental parameters monitored, their sensors and signal types.
N.B. a 200 ohm precision resistor (not shown) was used to convert each current signal to voltage.

• indicates 24 V. dc. power supply

Fig. 5.3

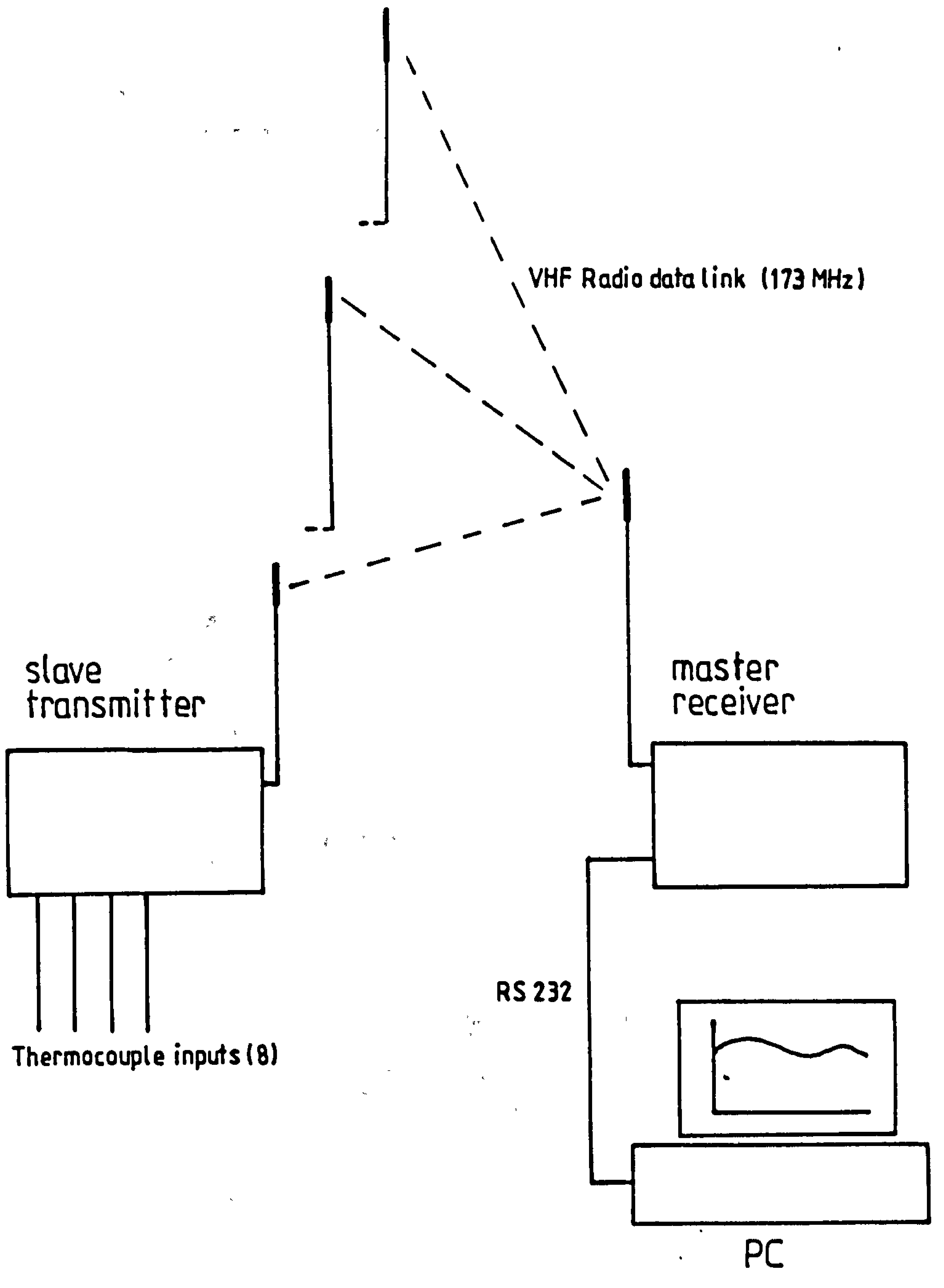


Diagram showing radio telemetry system used to collect plant data

Fig. 5.4

```
MAIN MENU                                                        PRESS

LOG     -   Start logging with screen display                      L
        -   Examine / Change current settings                      E
        -   Monitor logging in progress                            M
        -   Abort logging and file data                            A

TREND   -   Display  Current Data                                  D
        -   Display   Filed  Data                                  F
        -   Exchange  Filed  Data                                  X

MODE    -   Screen Save                                            V
        -   Key  on/off                                            K
        -   Go  to  DOS

STATUS  -   LOGGING ON
        -   BR16021.DAT LOADED
        -   FILES STORED ( 8 )  BR16021  BR17021  BR18021  BR19021  BR20021
BR21021  BR22021  BR23021

ENTER SELECTION
```

Main menu program BOILER

Fig. 5.5

```
CURRENT   SETTINGS

Monitored channels      First      1
                        Last       35
                        Option
Data Scan Interval                 900       secs

LOGGING MODE OPTIONS                                         CHOSEN
Single period     -   file after   0  readings
                           after   0  seconds
Multiple periods  -   file every   0  readings
                           every   0  seconds
Multiple periods  -   file at midnight                       ****
                           after   96  readings
CURRENT     STATUS
Date                               Fri 24-02-89
Current        Time                1132
Scan   started   at                0000
Last   reading   No                47
                 at                1129
Next data file   is                BR24021.dat
File   to  disc  at                2345
```

Settings menu

Fig. 5.6

CHOOSE DATA TO DISPLAY / OUTPUT	PRESS
BOILER NO 1	1
BOILER NO 2	2
BOILER NO 3	3
BOILER NO 4	4
BOILER NO 5	5
ALL BOILERS	A
WEATHER INF	W
MAIN MENU	M

1 END 2 MAIN 3 PREV 4 5 6 7 8 9 10

Display menu

Fig.5.7

```
DISPLAY / OUTPUT BOILER NO  3                                  PRESS

SELECT DATA REQUIRED

Efficiency                                                         E
Fuel flow                                                          F
Air flow                                                           A
Temperature flue gas                                               T
Oxygen flue gas                                                    O
Combustion air temperature                                         C



1 END   2 MAIN   3 PREV   4     5     6     7     8     9     10
```

Individual boiler menu

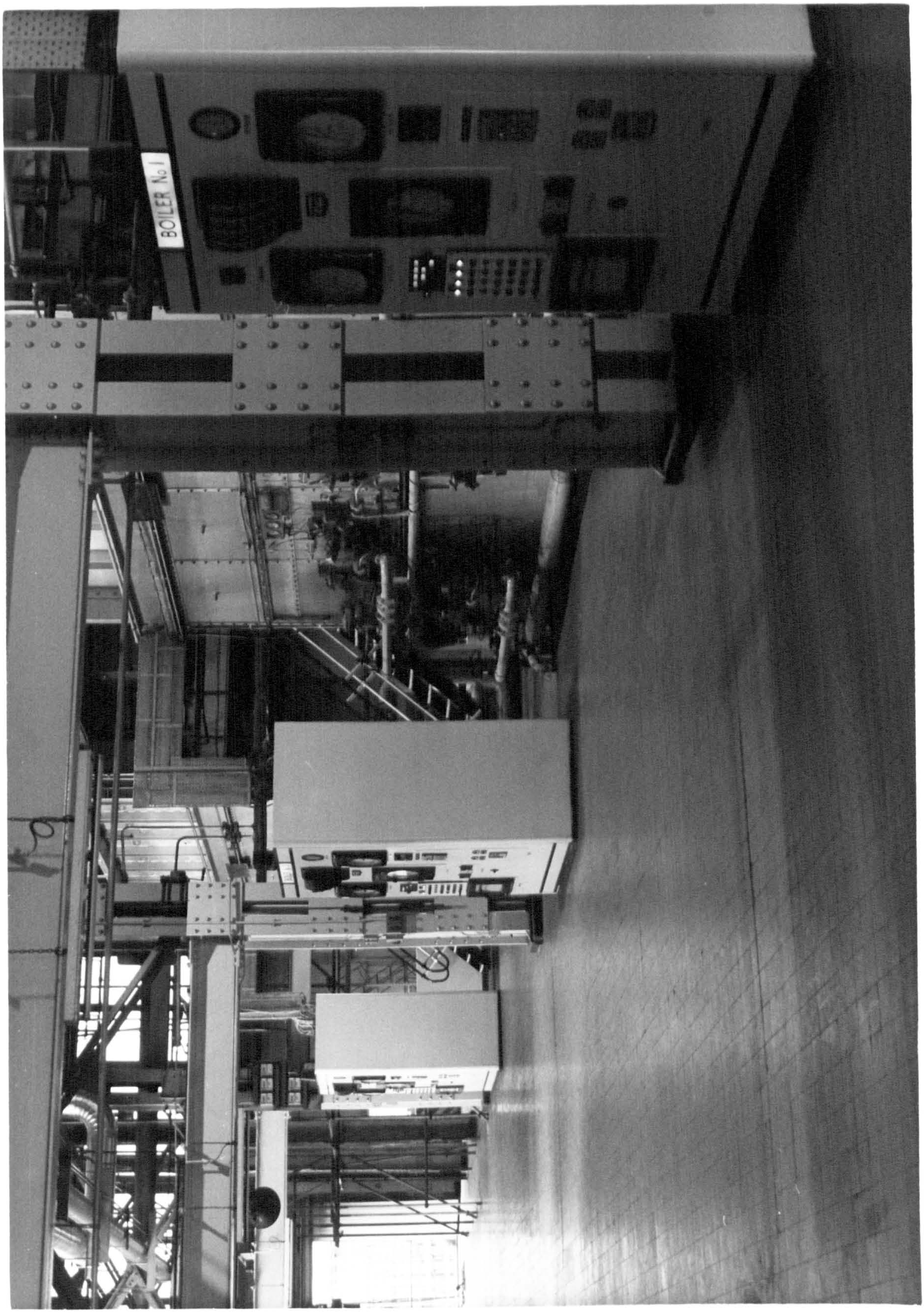
Fig.5.8

DISPLAY WEATHER DATA	PRESS
SELECT DATA REQUIRED	
Air Temperature	T
Relative Humidity	R
Solar Radiation (global)	S
Wind Speed	W
Wind Direction	D

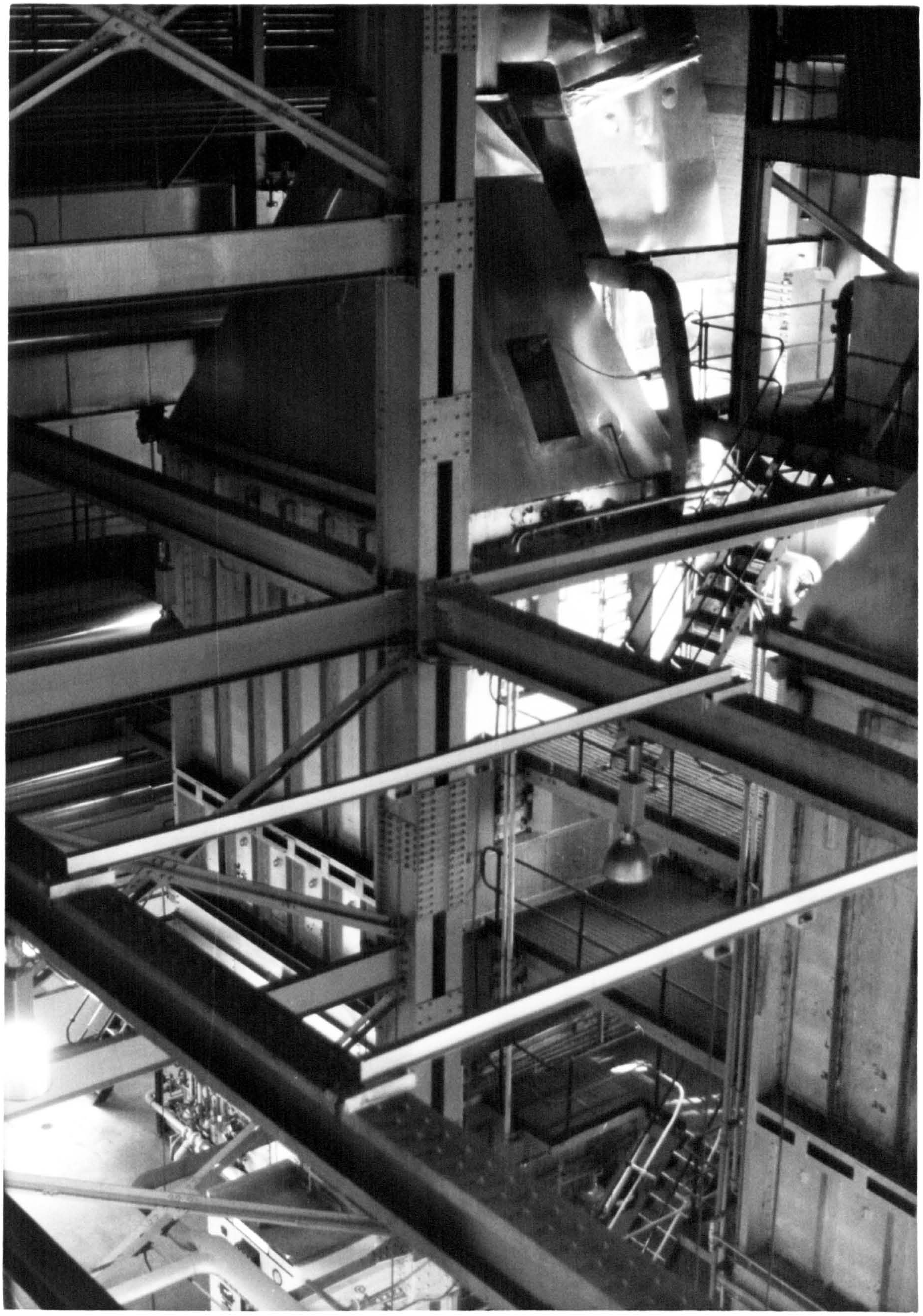
1 END 2 MAIN 3 PREV 4 5 6 7 8 9 10

Weather data menu

Fig. 5.9

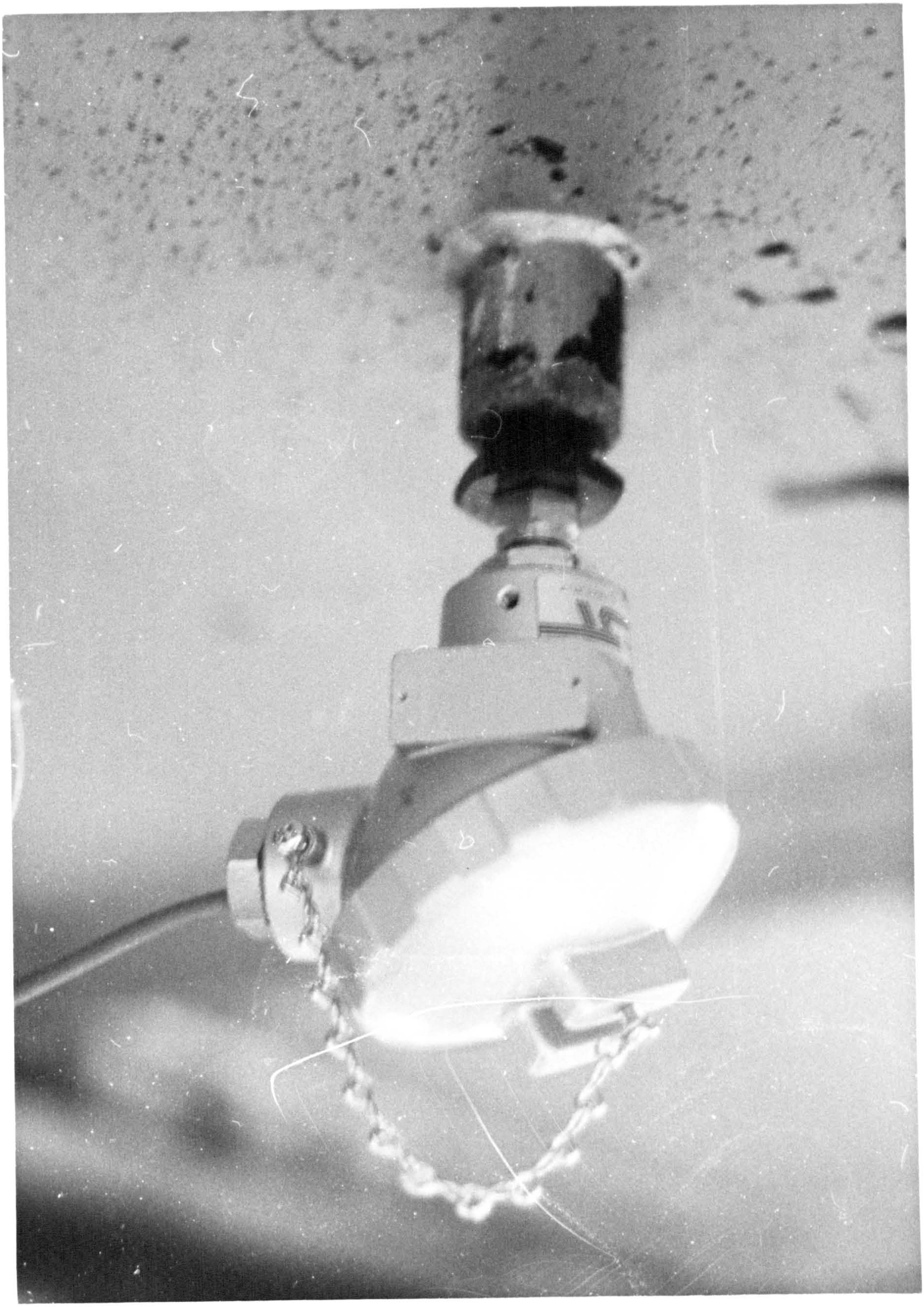


5.2(i) General view of the boilerhouse firing floor.

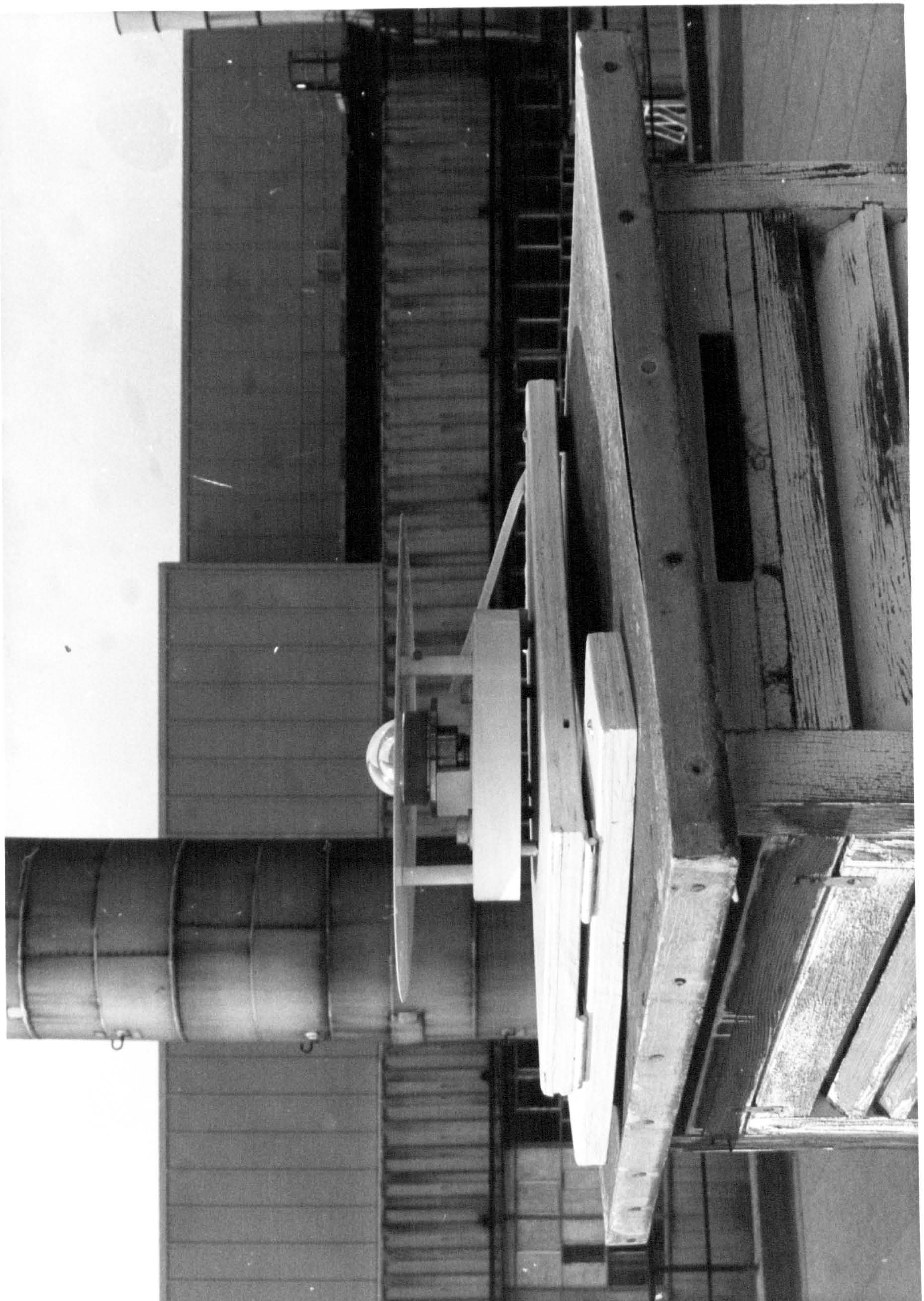


5.2(ii) Boiler No.2 showing: flue with oxygen sensor; inlet air ducting and pre-heated air ducting.

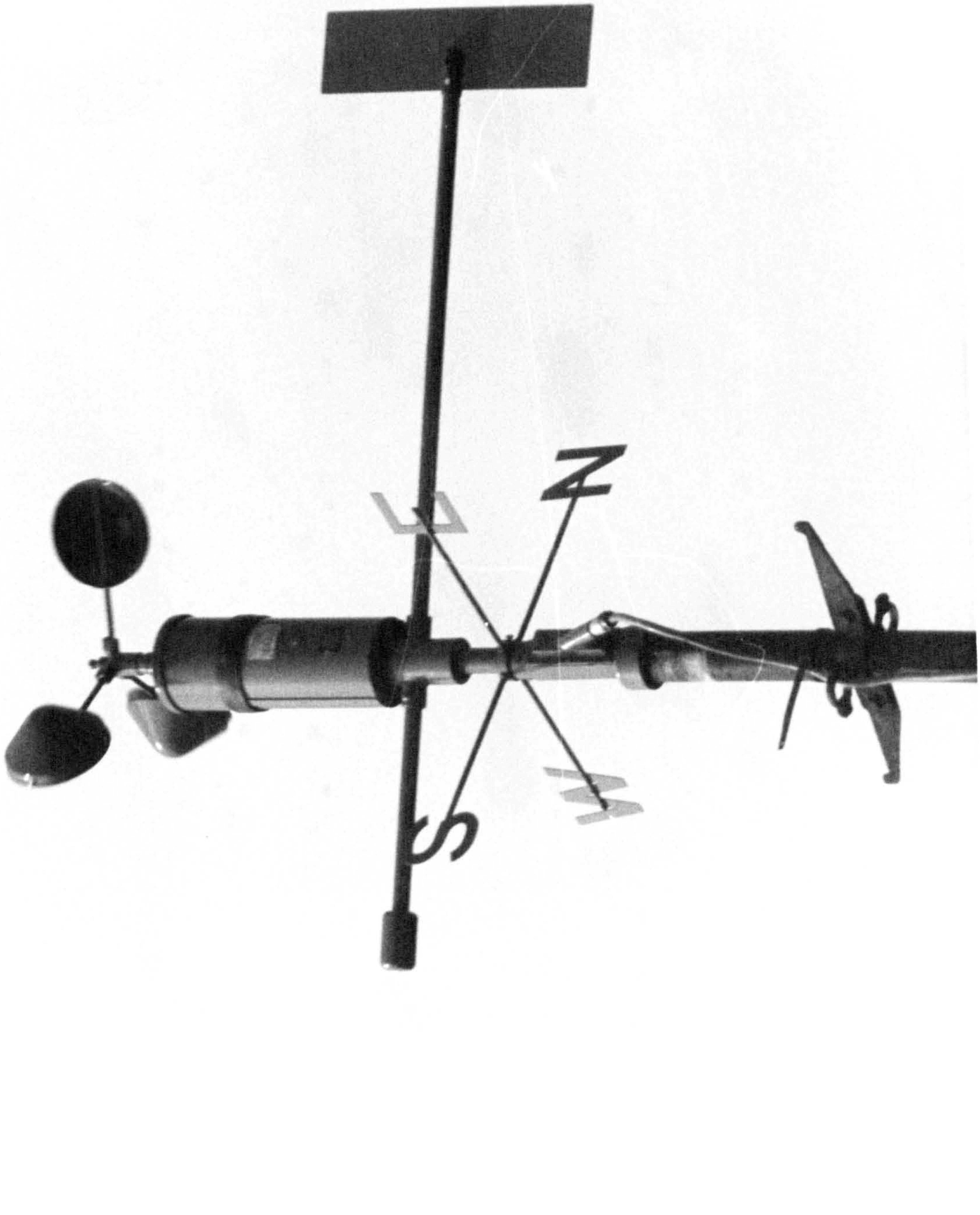
5.3(i) One of the GP1500 boiler controllers.



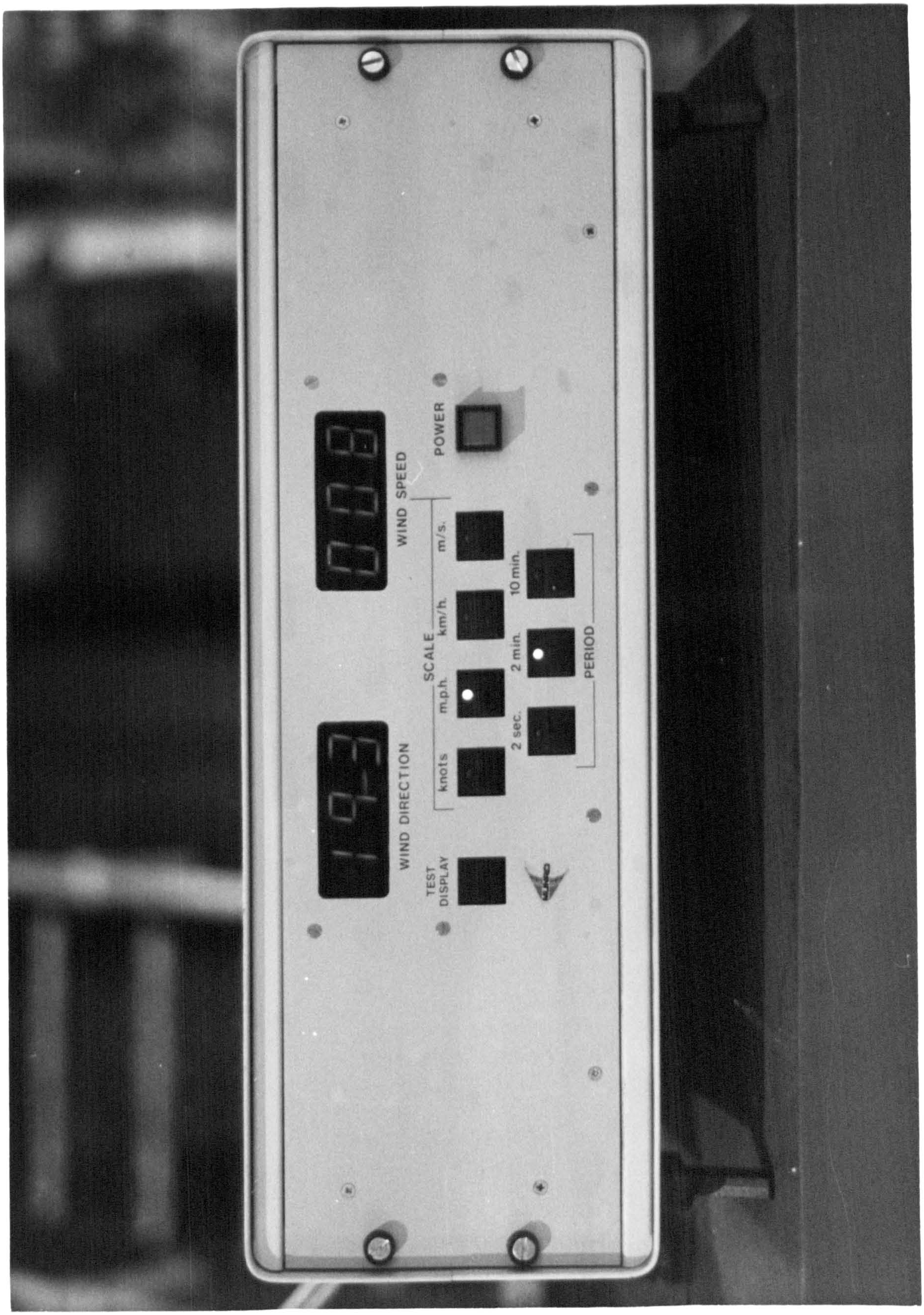
5.5.2(i) One of the combustion air temperature sensors.



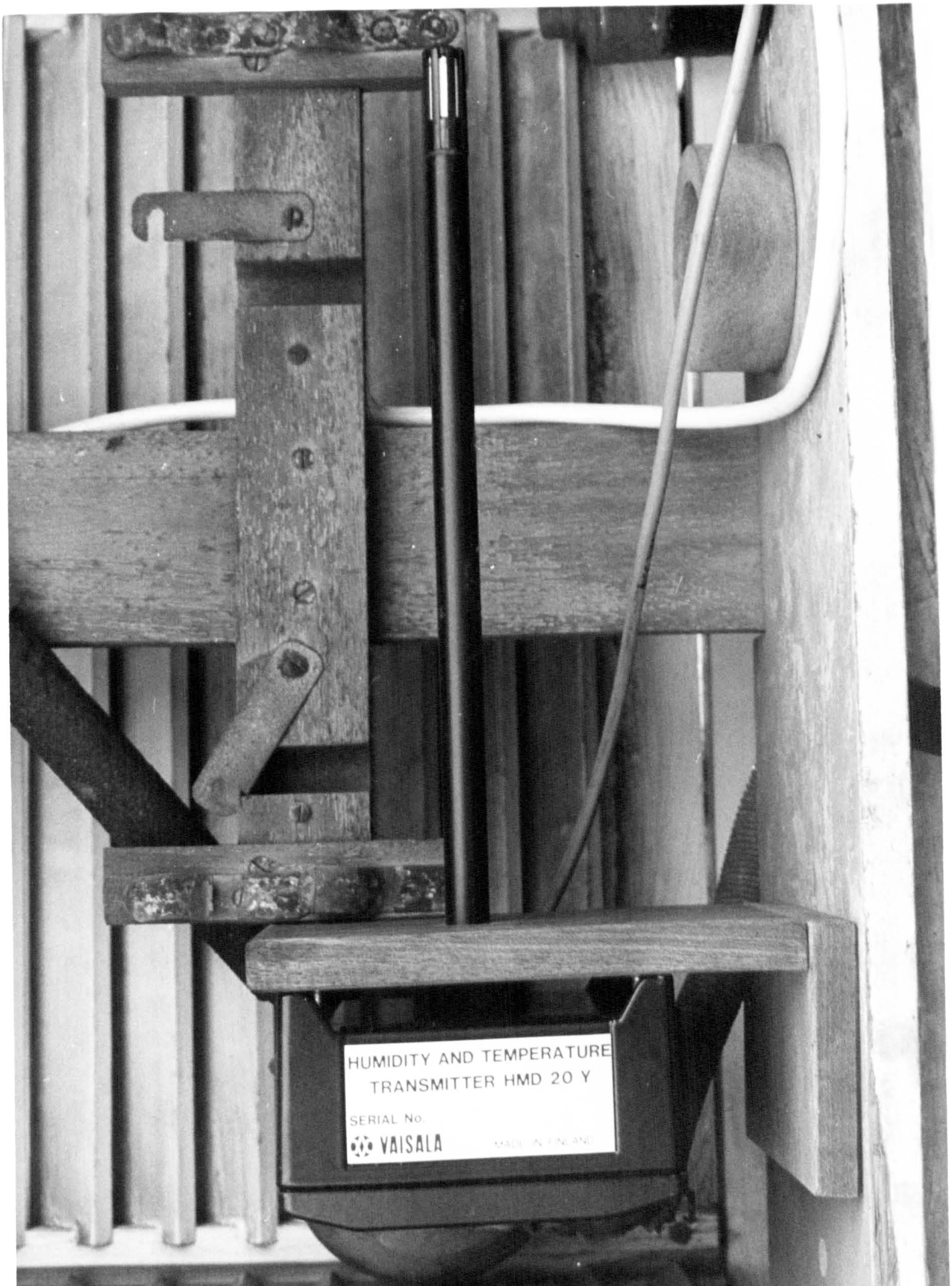
5.5.3(i) The Kipp and Zonen pyranometer on its adjustable base.



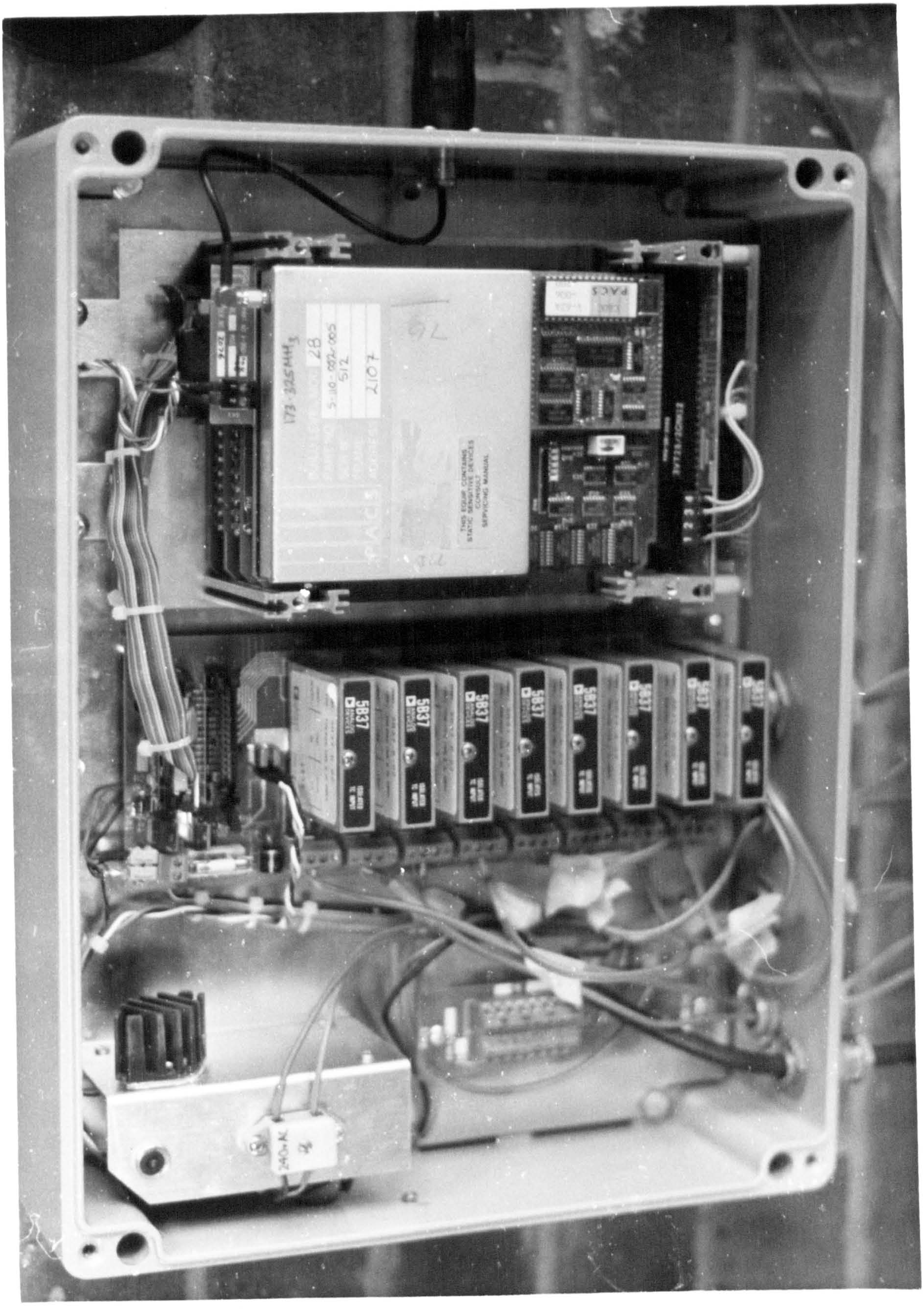
5.5.3(ii) The Munro wind speed and direction transmitter.



5.5.3(iii) The Munro wind display unit.

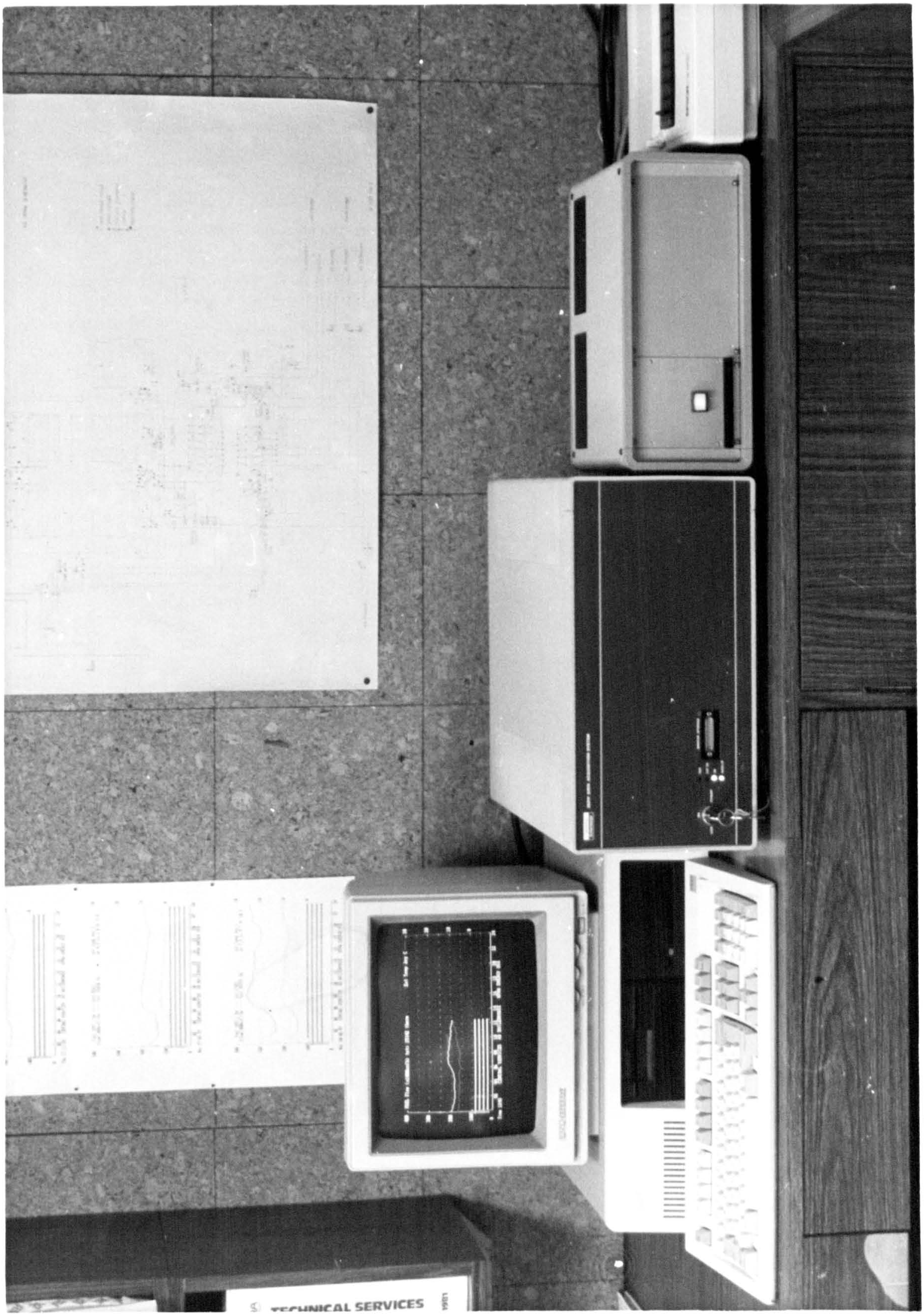


5.5.3.(iv) The Vaisala air temperature and relative humidity transmitter.



5.5.4(i) The radio telemetry slave data transmitter.

5.5.4(ii) A patch thermocouple on a heating mains pipe.



5.5.4(iii) The final monitoring system showing: computer; data logger; radio telemetry master station and printer.

CHAPTER 6

DETAILED ANALYSIS RESULTS

6.1 Introduction.

The monitoring system described in chapter 5 has been logging data since September 1988 when the basic elements of the system were completed. Some hardware and software problems occurred during commissioning so that the logged data is not continuous since then. Other interruptions in logging were caused by changes in the system: installing a different PC; installing a new data logger; changing the wiring arrangement; installing combustion air sensors; interfacing the radio telemetry system and the software modifications which were associated with these hardware changes.

As of February 1989, some 150 daily files of data had been accumulated and the results of the detailed analysis of some of this data is presented in this chapter together with the recommendations which can be drawn from the analysis. The limited time available for a research project such as this has meant that attempts to examine, in detail, the energy consumption of the the centralised high pressure hot water system with respect to several environmental parameters has not been possible and only outside air temperature has been considered here. However, the relevance of other parameters such as solar radiation and wind speed and direction has been observed and is noted below.

Whilst the general analysis described in earlier chapters is intended to heighten management awareness of energy flows, the results of the detailed energy analysis presented here is primarily intended to be of use to operating staff. Since the system monitors parameters in real time and presents information in a simple way, it enhances the operators' awareness of the energy consumption of the boilerhouse and thereby enables targets of consumption to be set.

6.2 Basic Data Analysis

6.2.1 Boiler Data

Six parameters for each of the five boilers are logged (see Fig. 5.8) and this data is used to determine the energy performance of the boilerhouse. The parameters are logged every 15 minutes and all logged values are stored in a daily file. The variation of any parameter with time may be viewed as the data is collected (i.e. in real time) or from the daily data files which are held on disc. Hence, trends for any parameter may be viewed over a period of hours, days or months - this enables any observed discrepancies to be investigated. Furthermore, the ability to trend parameters on a daily basis encourages operators to account for the shape of the trend which is a first step towards changing procedures to reduce energy consumption.

The variation in fuel flow for boiler number 3 for Monday 17th October 1988 is shown in fig. 6.1. Over the previous week-end two other boilers had been running and this extra boiler had been brought on-line in anticipation of the increased energy demand from production start-up on Monday morning. The vertical axis measures thousands of standard cubic feet of gas per hour (scfh) and fuel flows of 100,000 scfh have been experienced. However, the working maximum fuel flow rate is taken as about 80,000 scfh which approximately corresponds to the MCR (Mean continuous rating) for each boiler of 80 million BTU/hr.

The boiler is brought on-line at 0000 hours and the fuel flow rapidly rises to about 58,000 scfh and then falls to level off at about 42,000 scfh after about two hours. This peak in fuel flow which occurs for all three boilers is explained as follows:

* the third boiler is brought on-line

* extra circulating pumps are started

* the water flow rate through the boilers increases with a fixed flow temperature (180 C) and the same return temperature as before

* hence the energy delivered increases with a corresponding increase in fuel consumption

* the increase in delivered energy has the effect of increasing the temperature of the return water and dissipating excessive energy through heat exchangers - hence energy is wasted

* as the temperature of the return water increases, the energy required from the boilers to produce the temperature differential reduces and the fuel consumption drops

* the total fuel flow returns to approximately its original value but the load is now shared between three rather than two boilers.

The total fuel consumption for all the boilers (see fig. 6.19) shows a similar peak lasting about two hours and it is probable that this occurrence of fuel wastage could only be quantified by reference to a fuel trend. Approximately 30,000 scf of gas is wasted as a result of the operating procedures adopted and it is possible that shifting the start-up time for the third boiler to coincide with production start-up would remove this fuel peak and the associated energy wastage.

Further examination of the fuel trend for boiler number 3 shows a rise from 0600 to 0700 associated with production start-up and a fairly level fuel flow thereafter apart from the dip associated with the break in working shifts from 1700 to 2000.

The trend for the excess oxygen concentration in the flue gas for the same boiler on the same day is shown in fig. 6.2. As the boiler comes on-line, the oxygen concentration drops from above 20% to less than 5%. As was mentioned earlier, this drop is used as an indicator that a boiler has come on-line. The concentration remains around 5% and a drop is noticeable at 0600 which corresponds to the increase in fuel consumption. Such a trend is useful in identifying a possible fault in the oxygen trim system for the boiler - as is the case here. If the oxygen trace in fig 6.2 is compared with that in fig. 6.3 (for a different boiler on a different day), it can be seen that the boiler in fig. 6.2 is trimming to higher oxygen concentrations than the boiler in fig. 6.3 despite the fact that the fuel flows for the two boilers are similar (cf. figs 6.1 and 6.4). This implies higher excess air, higher flue gas losses and wasted energy. The oxygen concentration trend in fig. 6.3 is used here as a target for the oxygen concentration of the boiler in fig. 6.2. Required modifications would probably incur improvements to the air metering system and/or the oxygen trim system.

The variation in the combustion air temperature for boiler number 1 on Wednesday 28th September 1988 is shown in fig. 6.5 and for boiler number 3 on Friday 25th November 1988 in fig. 6.6. Both these trends illustrate that these temperatures are not constant (as assumed in the controller efficiency algorithm used for each boiler) but may vary over a 5 C range in one day and may vary over a larger range if different days are considered. The efficiencies calculated in the program BOILER are based upon the instantaneous values of combustion air temperature as indicated by these trends.

The variation in efficiency for boiler number 3 on Friday 25th November is shown in fig. 6.7. The solid line is the efficiency figure as evaluated by the Westinghouse GP1500 boiler controller which, as mentioned in section 5.3, assumes a constant combustion air temperature of 37 C and a constant radiation loss of 3%. The dotted line is the efficiency calculated by the program BOILER (BS, 1972; BS, 1974) and uses the instantaneous value of the combustion air temperature, as shown in fig. 6.6, the instantaneous value of the flue gas temperature (see fig. 6.8) and a percentage radiation loss which increases as the boiler load decreases. The difference between the two plots is mainly due to the different ways of accounting for the radiation loss and hence is less pronounced when the boiler is on high load between 0800 and 1200 than at other times. The maximum difference in the two efficiency figures for this boiler is seen as about 2%. Boiler number 5 on the same day (see fig. 6.9) shows a much larger discrepancy and this is attributed to other errors in the GP1500 controller efficiency algorithm.

6.2.2 Weather Data

Five weather parameters were monitored as listed in fig. 5.9, the most important of which is outside air temperature, and as mentioned in section 6.1, time limitations have enabled only passing mention to be made of the others, although their relevance to energy consumption is evident.

The outside air temperature and the relative humidity profiles for Tuesday 6th September 1988 are shown in figs. 6.10 and 6.11 respectively. The air temperature data is used in conjunction with fuel consumption data, to target energy use for the generation of high pressure hot-water (HPHW) (see section 6.4). Relative humidity was considered of interest for targeting energy used by air replacement plant which supplied air with a specified temperature and humidity to a paint shop 'clean room'. Energy targeting for this plant has not been dealt with here.

Examples of the wind speed and wind direction profiles are given in figs 6.12 and 6.13 respectively for Wednesday 7th September 1988. These are useful, since high wind speeds increase infiltration rates, and during heating months, lead to reduced comfort conditions. A real time display of wind speed and direction can alert boilerhouse staff to the onset of such conditions and to where they may occur. For example, in one factory block with large areas of south-facing glazing, reduced comfort conditions were identified from the profiles as being caused by strong southerly winds.

A trend of solar insolation (global) for Monday 10th October 1988 is shown in fig. 6.14. This parameter is of particular interest in autumn and spring when space heating is being provided and values of daily irradiance may be substantial as is the case here. This leads to over-heating and energy wastage particularly in areas with south-facing glazing - generally remedied by opening windows. The solar trend may be used to forewarn operating staff of imminent over-heating and the solution would then be to reduce or temporarily stop heating circulation to the affected areas. Ideally, such action should be carried out with reference to actual space temperatures and this necessitates reference to plant data which is dealt with in the following section.

6.2.3 Plant Data

At the plant studied the local control of space heating particularly in factory blocks was often absent or inoperative and hence the resulting energy wastage was considerable. From the viewpoint of energy conservation, it is considered that operators of any large centralised heating system need to be aware of space and process temperatures at various points within the plant.

The variation in internal air temperature for one of the blocks at the plant studied for Friday 17th February 1989 is shown in fig. 6.15 and the external air temperature for the same day is shown in fig. 6.16. As a result of the inadequate local control of space heating, the internal air temperature approximately follows the external temperature. This is what one might expect if space heating energy is supplied at a constant rate without regard for the temperature achieved, as it is here. The over-heating in the afternoon is clearly apparent from fig. 6.15 with associated energy wastage. Operating staff need to be aware of such trends so that flow control may be utilised to reduce the space heating energy supplied. Recommendations to motorise some twenty valves to enable such control have been made and installation is planned for the 1989 summer closure.

The variation in flow (solid line) and return (dotted line) temperatures for one set of HPHW mains serving one of the factory blocks for Saturday 28th January 1989 is shown in fig. 6.17 as an example only. Since the flow rate of circulating water is approximately constant over the day, the energy delivered to the block is proportional to the differential between the flow and return temperatures. It has been observed on some mains (not yet equipped with radio telemetry data apparatus) that the differential temperature falls to only a few degrees C implying that no energy is being delivered and that the temperature differential results from distribution losses only. In this case maintaining water circulation serves only to dissipate energy to the environment. By observing the temperature trends like those shown in fig. 6.17, operating staff may stem this wastage by closing the appropriate valves.

6.3 Derived Data Analysis

Apart from displaying individual parameters for the boilers, the weather and the plant, the program BOILER performs the necessary calculations to enable the display of data which relates to the whole boilerhouse. A major benefit of a real time monitoring system is that derived data may be displayed as it is collected and then interpreted by the operator enabling any energy conserving actions to be taken. As all the data displays in this chapter are historical ones, a sample screen dump of a real time data display is included as an example in fig. 6.18. This is a copy of the screen display when entered via the All Boilers/Total cost options available from the menus on Tuesday 28th February 1989. The display lines and the two total figures for fuel cost and fuel flow relate to the time period from midnight to the time of the last scan which was 1145.

6.3.1 Total Fuel Flow

A plot of total fuel flow for all of the boilers for Monday 17th October 1988 is shown by the solid line in fig. 6.19 (NB. when filed data is displayed the program selects the most appropriate vertical axis which here ranges from 0 to 200 thousand scfh). The vertical axis to the right is scaled from -10 C (omitted for clarity) to 30 C and the temperature plot for the day is shown as a dotted line. The numbers 1 to 5 on the lowest quarter of the left vertical axis represent the numbers of the five boilers in the boilerhouse and the presence of thick solid horizontal lines to the right of these numbers indicate that the corresponding boiler is on (in this case boilers 1, 3 and 4 were on - boiler 3 being switched on just after midnight). The total fuel used is shown at the top right whilst the date appears at the bottom left.

The total fuel flow for Friday 9th September 1988, in fig. 6.20, shows an inverse variation with external temperature and also shows that, for at least half of the day, the fuel flow is less than the maximum for one boiler - yet two boilers remain on-line. This results from a flow limitation (mentioned earlier and detailed later in section 6.5) which implies that the circulation required cannot be maintained with one boiler alone.

6.3.2 Overall Efficiency

The overall efficiency for all the boilers is found by weighting the efficiency of each boiler on-line by the fractional fuel flow through that boiler. A plot of the overall efficiency of the boilers for the same day is shown in fig. 6.21 as the solid line. Again the external temperature and the boiler-on lines are plotted. It is clear that with two lightly loaded boilers on-line, the average efficiency is relatively low. The maximum efficiency reached for the day of about 78% is some 2-3% lower than the norm (i.e. the average efficiency expected when the boilers are running close to full load) and the minimum efficiency of less than 74% corresponding to the minimum fuel flow for the day is very low relative to the norm. The low average efficiency apparent for this day with the attendant wastage of energy results directly from the necessity of keeping two lightly loaded boilers on-line which in turn results from flow limitations within the boilerhouse (see section 6.5).

6.3.3 Total Fuel Cost

The instantaneous total fuel cost is derived from the total fuel flow and is the third screen available from the All Boilers Menu list of options. Originally, the screen showed only fuel cost and outside temperature but has been modified to display total fuel flow and boiler-on lines also. A copy of the screen for Wednesday 7th December 1988 is shown in fig. 6.22 where the left vertical axis serves to measure the instantaneous fuel cost in pounds (sterling) per hour and the instantaneous fuel flow in thousands of scfh. The additions to the basic fuel cost display enable a print-out of a single screen, called the HPHW report, to be used as a summary of the boilerhouse performance for that day. The total cost of fuel, the total fuel (in therms) used and the average, lowest and highest temperatures for the day are also shown.

6.4 Targeting Energy Use

Energy savings from operational changes can be made on the basis of the interpretation of the HPHW report in real time and examples which illustrate the opportunity for such changes are given in section 6.4.1. Trends which relate to energy consumption over a period of weeks or months are useful in identifying other opportunities for conservation and these are considered in section 6.4.2.

6.4.1 Targeting by comparison

Example 1 Sunday 23rd-Monday 24th October 1988

It is common practise to fire an extra boiler around midnight on Sunday to accommodate the extra requirements of production start-up on Monday morning. Whilst this is often necessary, it is not always the case and figures 6.23 and 6.24 illustrate how this practise may lead to fuel wastage. Reference to fig. 6.23 shows that, at midnight, there are two boilers on, a fuel flow of some 100,000 scf per hour (i.e. 50,000 scf/hr for each boiler - well below the 80,000 scf/hr boiler limit), and a relatively stable outside temperature of 11-12 degC. A third boiler is fired just after midnight (see fig. 6.24) and causes a temporary rise in fuel flow and cost associated with increased pumping (NB. figs 6.23 and 6.24 use different vertical scales). After an hour, the fuel flow and cost settle down to higher values than before midnight although the external temperature is actually higher. It is therefore apparent that the third boiler is unnecessary and serves only to increase the fuel used and the hourly cost - it is finally taken off-line at 1230 on Monday.

Example 2 Sunday 4th Sept. and Sunday 9th Oct. 1988

If the first eight hours for each of these two days are compared (Sunday 4th September in fig. 6.25 and Sunday 9th October in fig. 6.26), a large difference in cost is apparent. On the 4th September, the average temperature for the first eight hours is less than 10 C and the average cost is about £120 per hour. On the 9th October, the average temperature for the first eight hours is above 10 C yet the average cost is about £220 per hour i.e. the cost is almost doubled when the outside temperature is higher. The reason for this difference is that the heating mains were opened at the end of September and thus factory and office blocks were being heated unnecessarily on the 9th October. Comparison of the total cost for the two days which have similar minimum temperatures and mean temperatures differing by about 2 C shows a figure of £2871 compared with £5327. This 2 C difference in mean temperature accounts for about £500 of the £2500 difference in cost - the remaining £2000 must be regarded as wasted in overheating factory and office blocks. This could have been avoided by reference to the HPHW report at midnight on Saturday 8th October which shows:

Three boilers on
Heating mains open (not shown)
High external temperature of 13 C
Total gas flow of 140,000scf/hr

This suggests the following action for energy conservation:

Take one boiler off-line
Close the heating mains
with cost savings for the day of about £2000

Other cases are in evidence from the monitored data which indicate wastage of energy associated with the lack of control of HPHW supply.

6.4.2 Targeting by trend

From the previous section it is apparent that energy wastage may often be identified by comparing HPHW reports for two days. If larger numbers of reports are to be compared then a different method is required. A simple way of comparison is to plot the daily HPHW cost of fuel against daily average temperature, as shown in fig. 6.27 for days in September, October and November 1988 (NB. the days shown are not continuous and weekends are excluded). A solid line is shown when heating mains are closed and a dotted line when they are open. The number of boilers on-line is also indicated.

The following observations may be made from the cost temperature graph:

* The general trend of the points shows, as expected, that the cost increases as the average temperature drops.

* For the warmest days shown in early September, the cost is approximately £3000 per day and this may be taken as a minimum cost to provide the process requirements of the plant since no space heating is supplied.

* For the coldest days shown in November with temperatures of 6 - 7 C, the cost increases to about £ 8000 per day to provide both process and heating requirements.

* The points falling in the middle range of temperature, from 9 - 16 C, show a wide spread of costs and this is again due to inadequate control. If two days are compared with the same average temperature i.e. 29/9 (Thursday) and 12/10 (Wednesday), a difference in cost of over £1400 is found. This is attributed to the fact that 29/9 has two boilers on and heating off whilst 12/10 has three boilers on and heating on. This specific analysis illustrating a case of energy wastage as a result of poor control exemplifies the observations made in section 4.6.2 of the general analysis.

* The wide scatter of points shown in fig. 6.27 testifies to the poor control strategies currently employed and the potential for significant energy savings.

* One effect which contributes towards the general scatter of points and energy wastage which is repeatedly apparent from the figure is a type of operational hysteresis which is referred to here as the drifting cost effect. Two examples are given.

* Consider the train of points for the days 9/9 to 16/9 (missing days do not affect the argument).

9/9 to 13/9	the external temperature drops and the cost increases as expected
13/9 to 14/9	a further temperature drop is accompanied by a further cost rise
14/9 to 16/9	the temperature rises but the cost does not return along the 9/9 - 13/9 line but drifts off to an unnecessarily high value

* Consider the train of points for the days 27/9 to 5/10.

27/9 to 29/9	the temperature drops and the cost increases as expected
29/9 to 30/9	as the temperature drops further, another boiler is brought on-line, the heating mains are opened and the cost increases
30/9 to 5/10	the temperature rises but the cost does not return along the 30/9 - 29/9 line but again drifts off to an unnecessarily high value. The daily costs for 5/10 and 28/9, both Wednesdays, a week apart with identical average temperatures differ by £ 1360.

6.4.3 Summary

The previous sections demonstrate how the data from the monitoring system, be it directly displayed or derived, may be used to: identify specific cases of energy wastage; identify trends which lead to wastage; provide the information necessary for better understanding of a large centralised energy system and provide the information necessary to improve control.

6.5 Flow Analysis

It was stated in section 6.3.2 that the necessity of keeping two lightly loaded boilers on-line, with an attendant loss in overall efficiency resulted from flow limitations within the boilerhouse. The rated maximum water flow for each boiler is of the order of 800,000 lbs per hour and even in the summer months, the total flow through all mains is of the order of three million lbs per hour. Whilst by-pass arrangements exist, they are inadequate and extra boilers are required to cope with the flow demands whereas one boiler may cope with the heat demands. To rectify this situation, increasing the piping size of the process by-pass has been suggested and in order to do this, it was necessary to estimate current by-pass flows which are not metered.

6.5.1 Flow Calculation

Whilst the calculation of the by-pass flows can be easily performed manually, a computer program was written for the calculation, which would also enable staff to quickly see the effects of changing the flow temperature from the boilers.

The calculation procedure is as follows. The total process flow from the boilerhouse is found by summing the individual flowmeter readings for all the process mains. The total heat to the process mains is then found from the various process flows and the corresponding flow and return temperatures. The mean process return temperature is found from the process flows and respective return temperatures. By equating the total heat to the process mains with the heat delivered to the process mains from the boilers knowing the boiler flow temperature and the mean process return temperature, the process flow through the boilers is determined. Knowing the total process flow then enables the process by-pass flow to be found. A similar calculation is then performed for the heating mains. The sum of the process and heating flows through the boilers is then compared with the sum of the observed boiler flows found from the individual boiler flowmeters. Also, the mean return temperature to the boilers from the mixed process and heating returns is calculated and this is compared with the observed value. Further, the total heat supplied to both the process and heating mains is found from adding the two calculated values and this is compared with the observed total heat supplied to the water from the boilers on-line. Hence, three calculated figures: the total boiler flow; the mean return temperature and the total heat supplied to the water are compared with the corresponding observed ones. If the agreement is reasonably good, then this is taken as an indication that the calculated values of the process and heating flows through the mixing by-passes, which are the quantities of interest since they cannot be directly measured, are close to their actual values.

6.5.2 Flow Results

The computer output of the flow analysis calculation is shown in fig. 6.28 for values taken on

January 27th 1989. The calculated flow through the boilers of 2.98 million lbs per hour compares with an observed value of 2.96 million lbs per hour whilst the calculated return temperature of 150.6 C compares with an observed value of 150.75 C. The calculated heat delivered, 131 million BTU/hr compares with an observed figure of 130 million BTU/hr. In line with what has been previously stated, it can be seen from fig. 6.28 that the number of boilers required for the flow demand exceeds that required for the heat demand.

As the agreement between calculated and observed figures is reasonably good, the values of the process by-pass mixing, about 900,000 lbs per hour, and the heating mixing, about 1,300,000 lbs per hour, are assumed to be fairly accurate in this case. The value of the process by-pass mixing is taken as close to the maximum value, since the control valve is always wide open whereas the heating mixing flow may be much larger.

To reduce the number of boilers on-line for a given heat demand and realise improved overall efficiency for the boilerhouse, involves reducing the flow through the boilers with a corresponding increase through the by-passes and compensating for the reduced boiler flow by increasing the boiler flow temperature. To see the effects of possible flow modifications, the calculation is repeated in fig. 6.29, holding outgoing flows and temperatures constant, as dictated by space heating and process requirements but increasing the boiler flow temperature to 180 C. This has the effect of reducing the number of boilers on-line by one but requires increased mixing by-pass flows for both heating and process which cannot be currently realised owing to the size of the process by-pass.

The flow analysis has enabled by-pass flow requirements to be evaluated and the necessary modifications to be established. These modifications are being implemented during the 1989 annual closure.

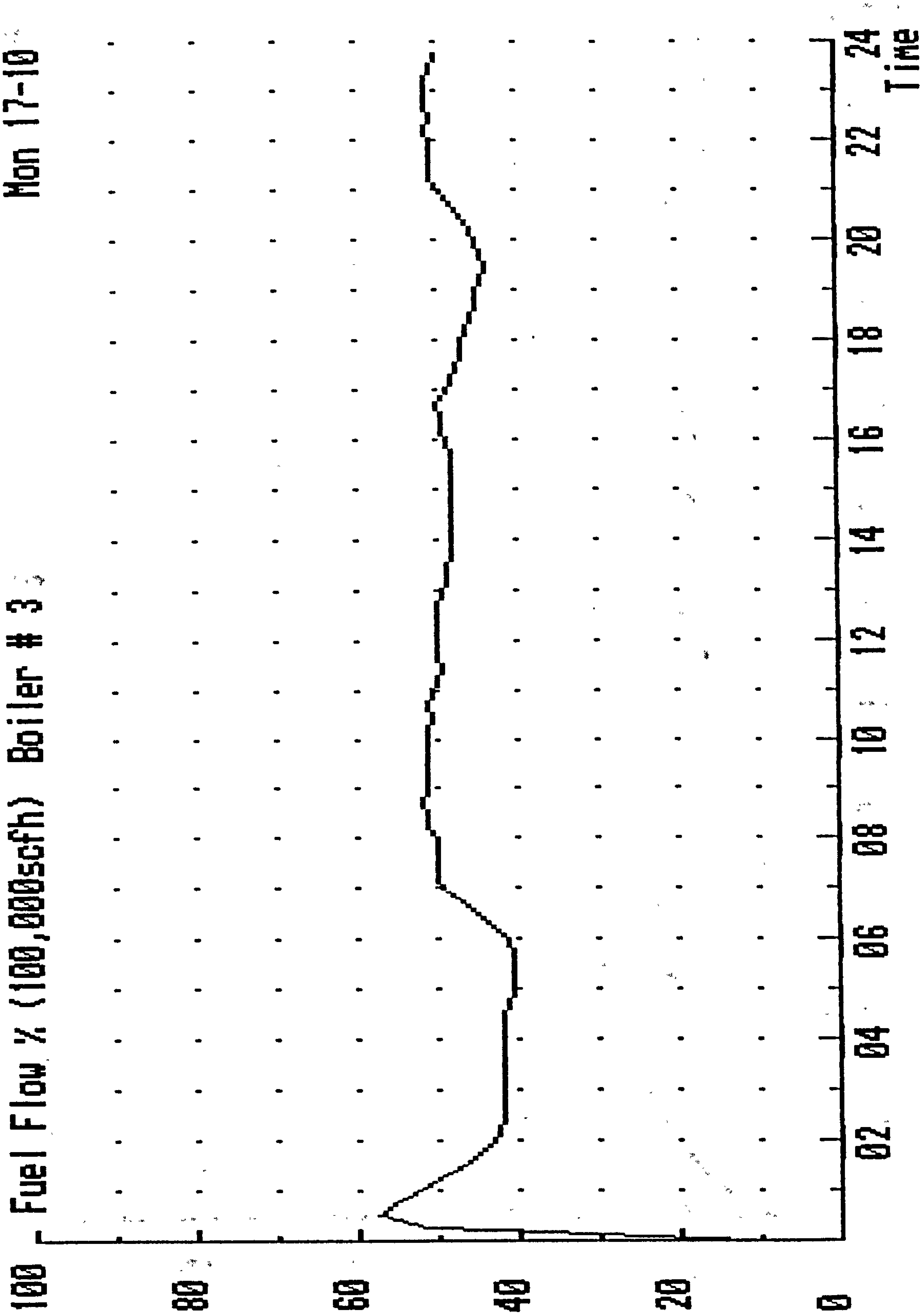

Fuel Flow % (100,000scfh) Boiler # 3
Mon 17-10
100
80
60
40
20
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.1

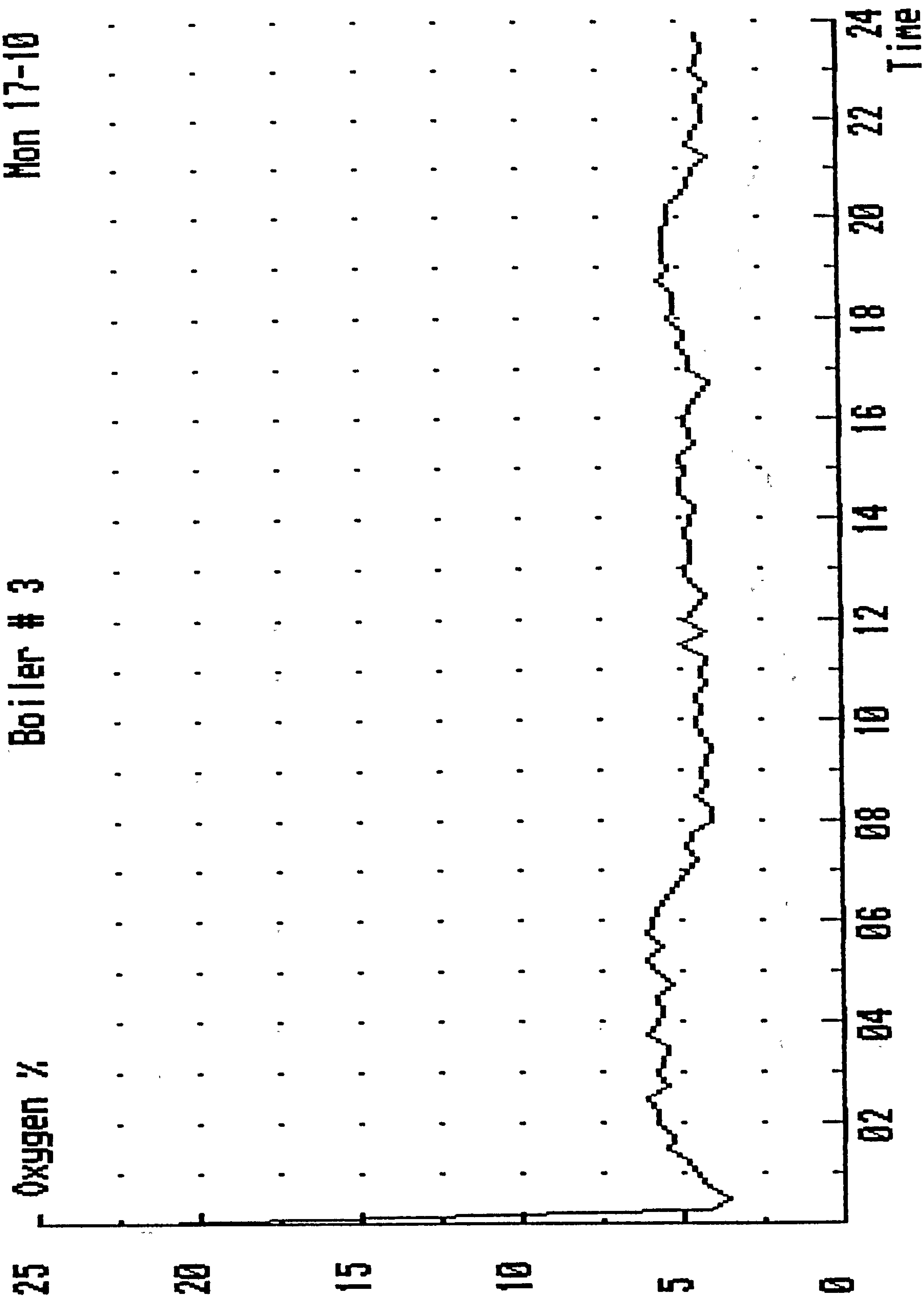

Oxygen %
Boiler # 3
Mon 17-10
Time
02
04
06
08
10
12
14
16
18
20
22
24
0
5
10
15
20
25

Fig. 6.2

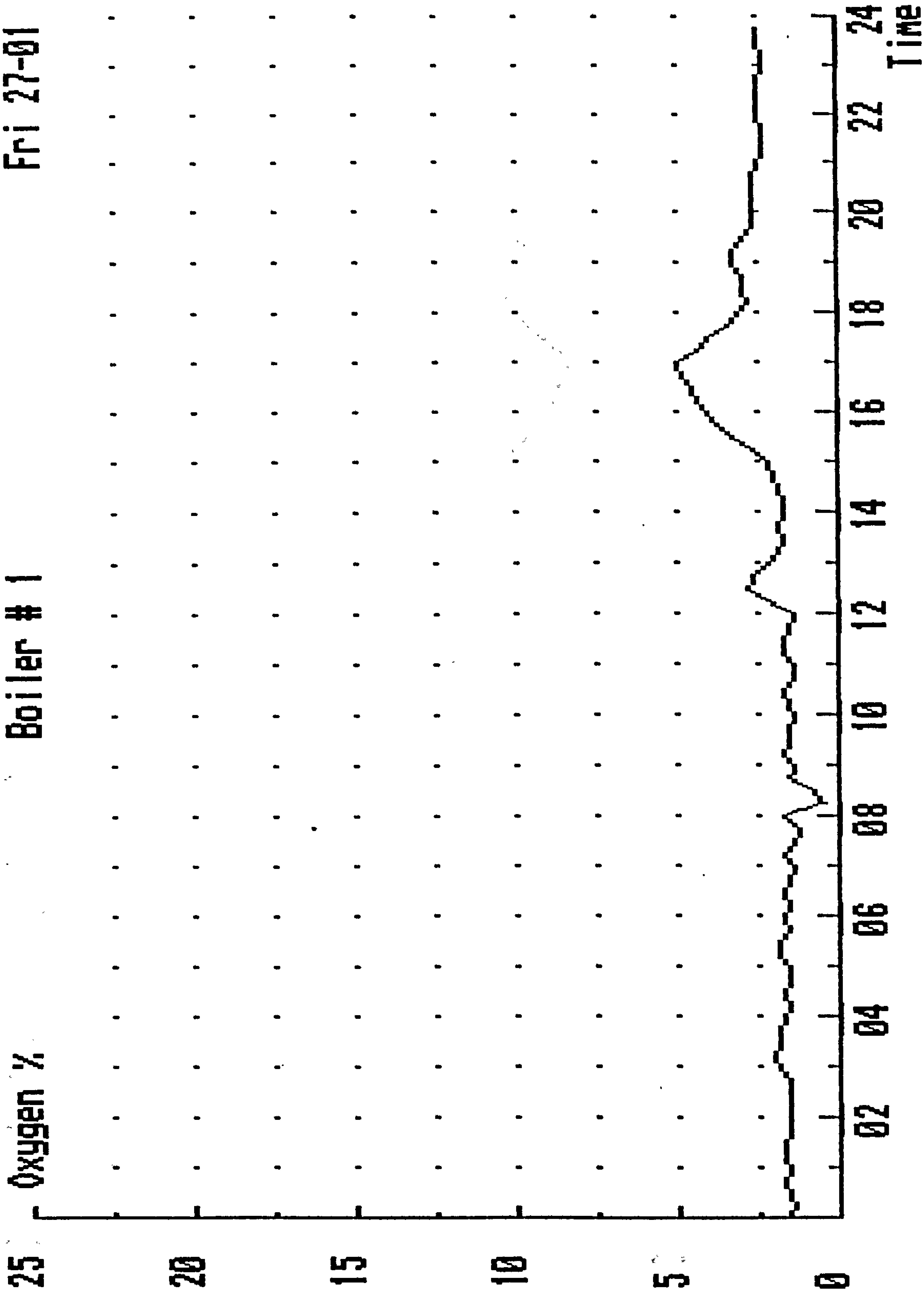

Oxygen %
Boiler # 1
Fri 27-01
25
20
15
10
5
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig.6.3

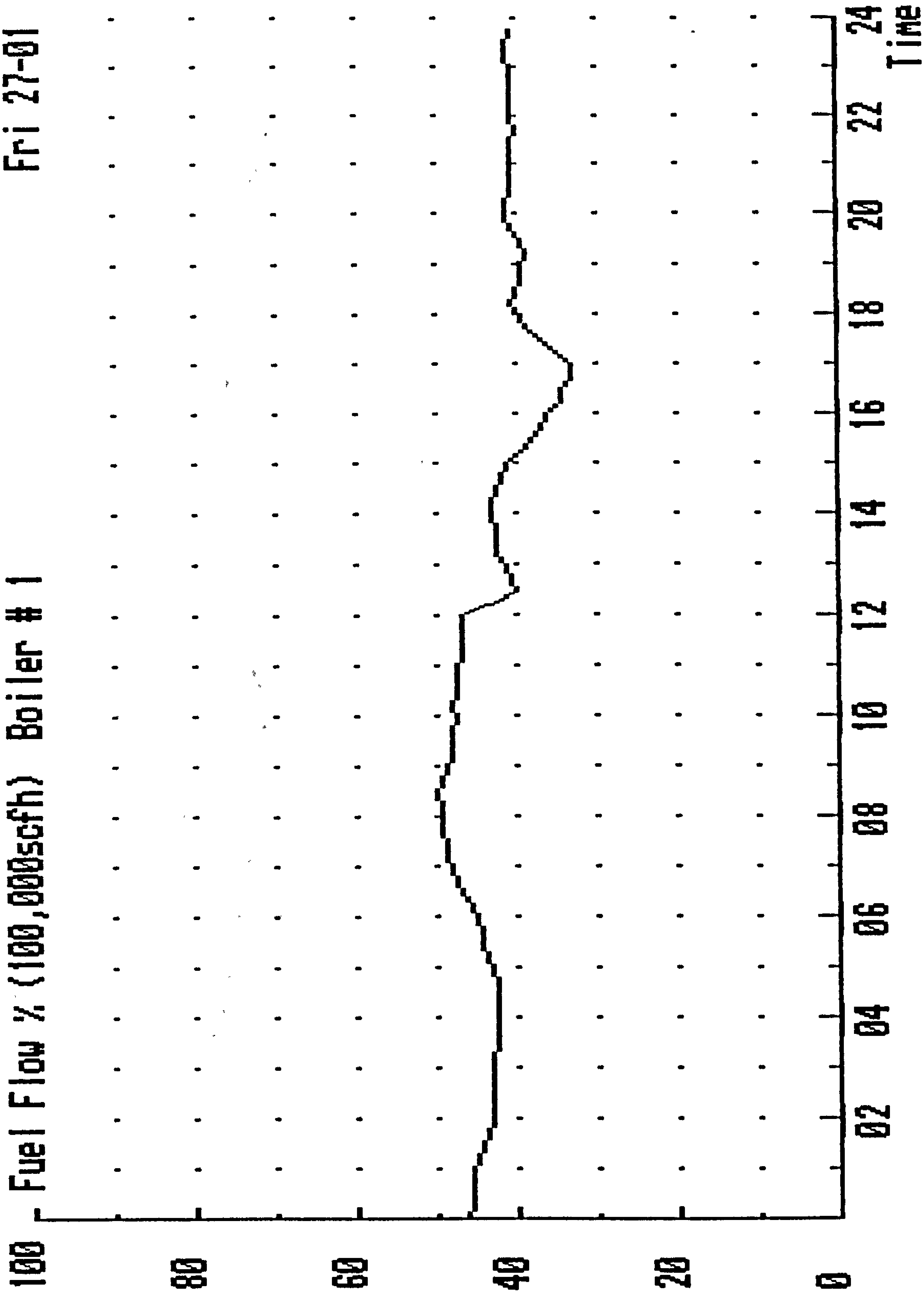

Fuel Flow % (100,000scfh) Boiler # 1
Fri 27-01
100
80
60
40
20
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.4

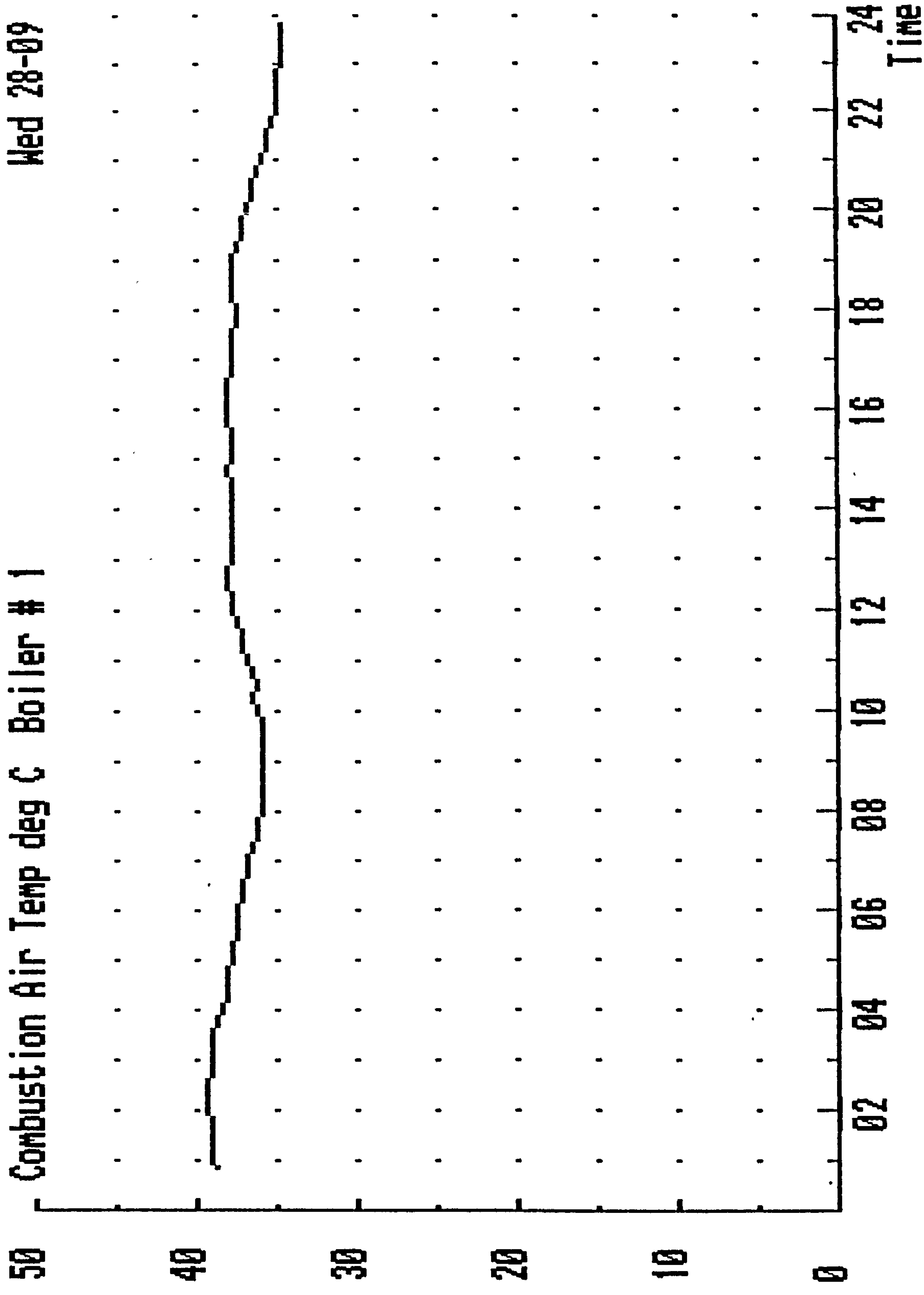
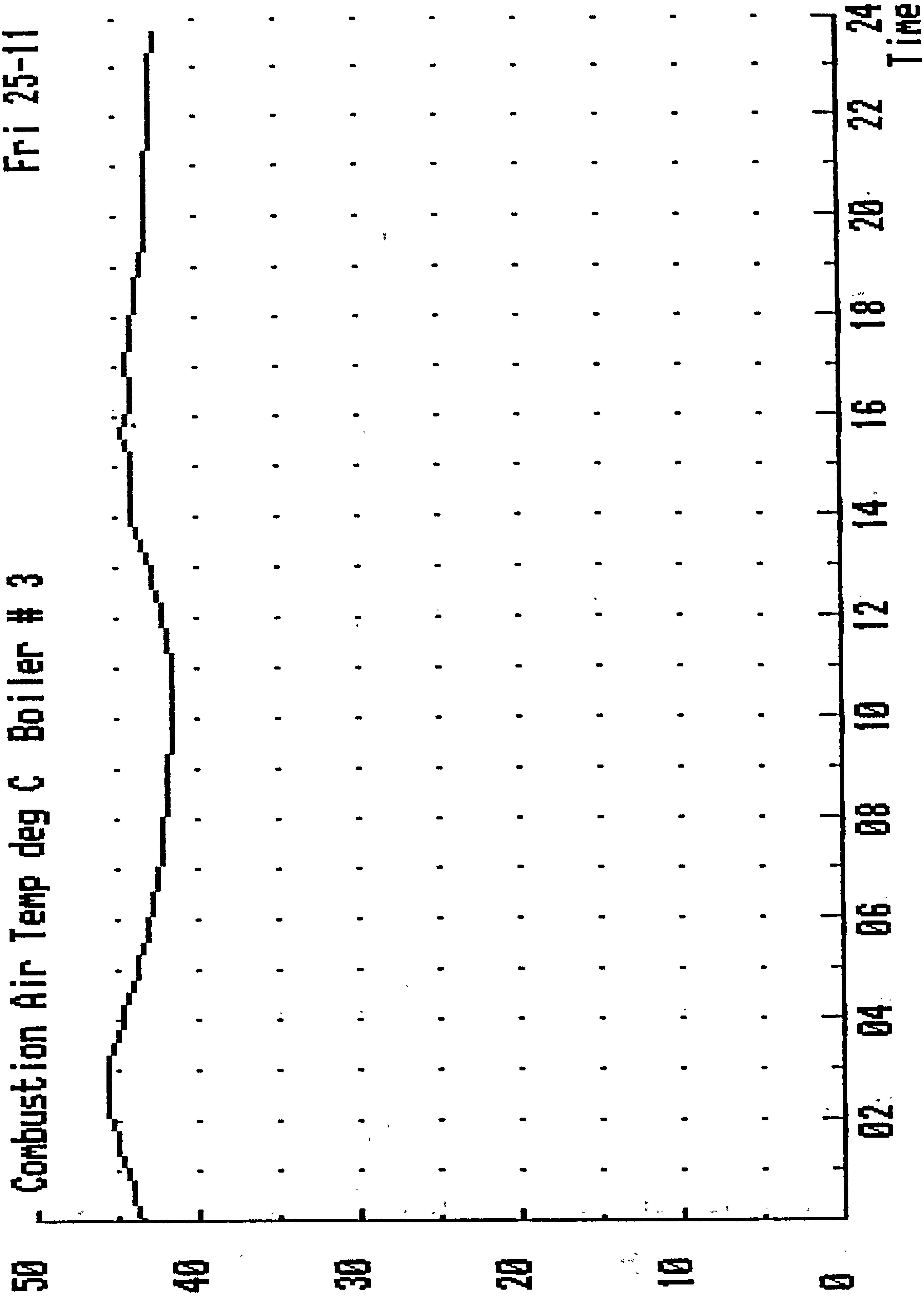

Combustion Air Temp deg C Boiler # 1
Wed 28-09
50
40
30
20
10
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.5



Combustion Air Temp deg C Boiler # 3
Fri 25-11
50
40
30
20
10
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.6

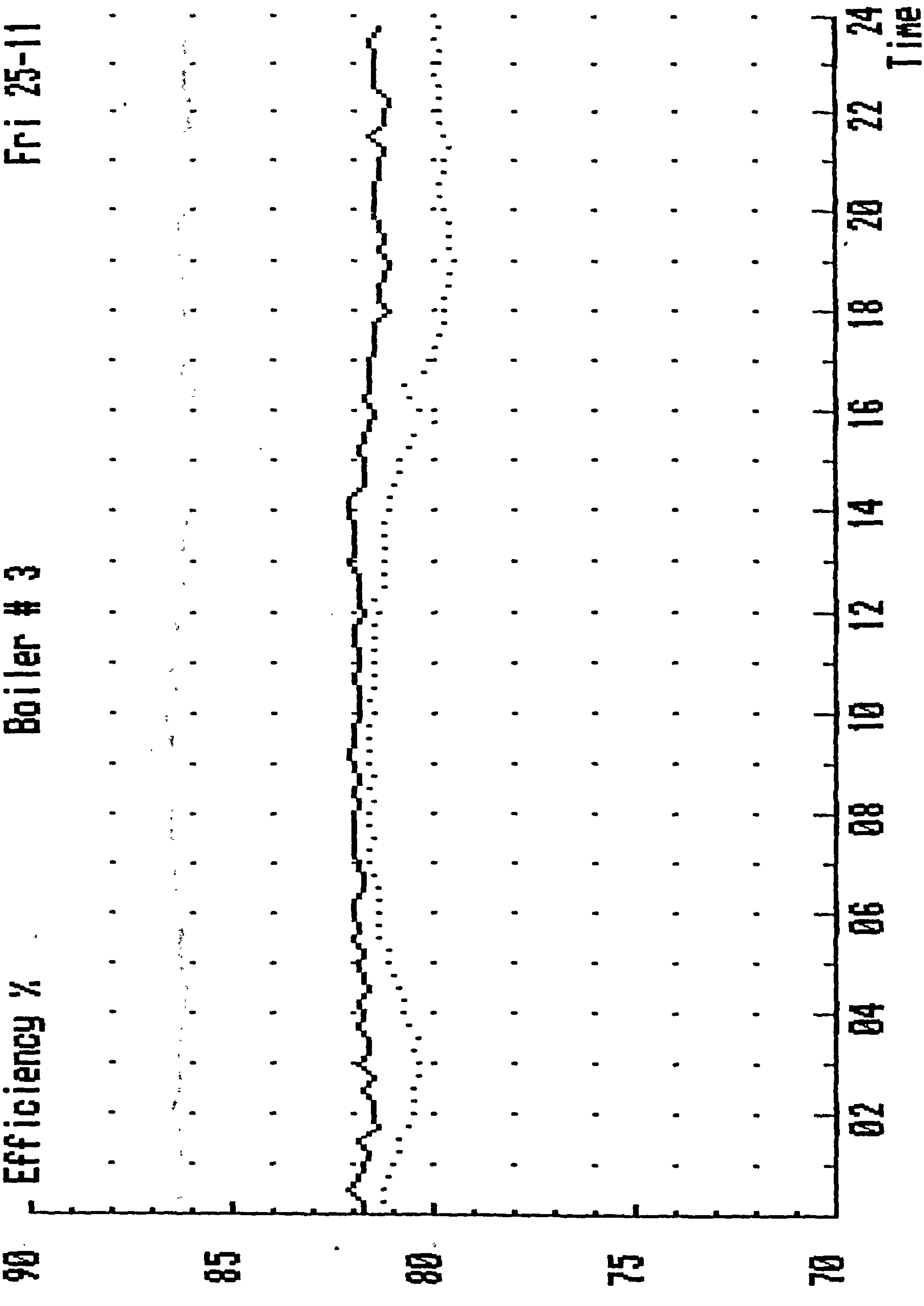

Efficiency %
Boiler # 3
Fri 25-11
90
85
80
75
70
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.7

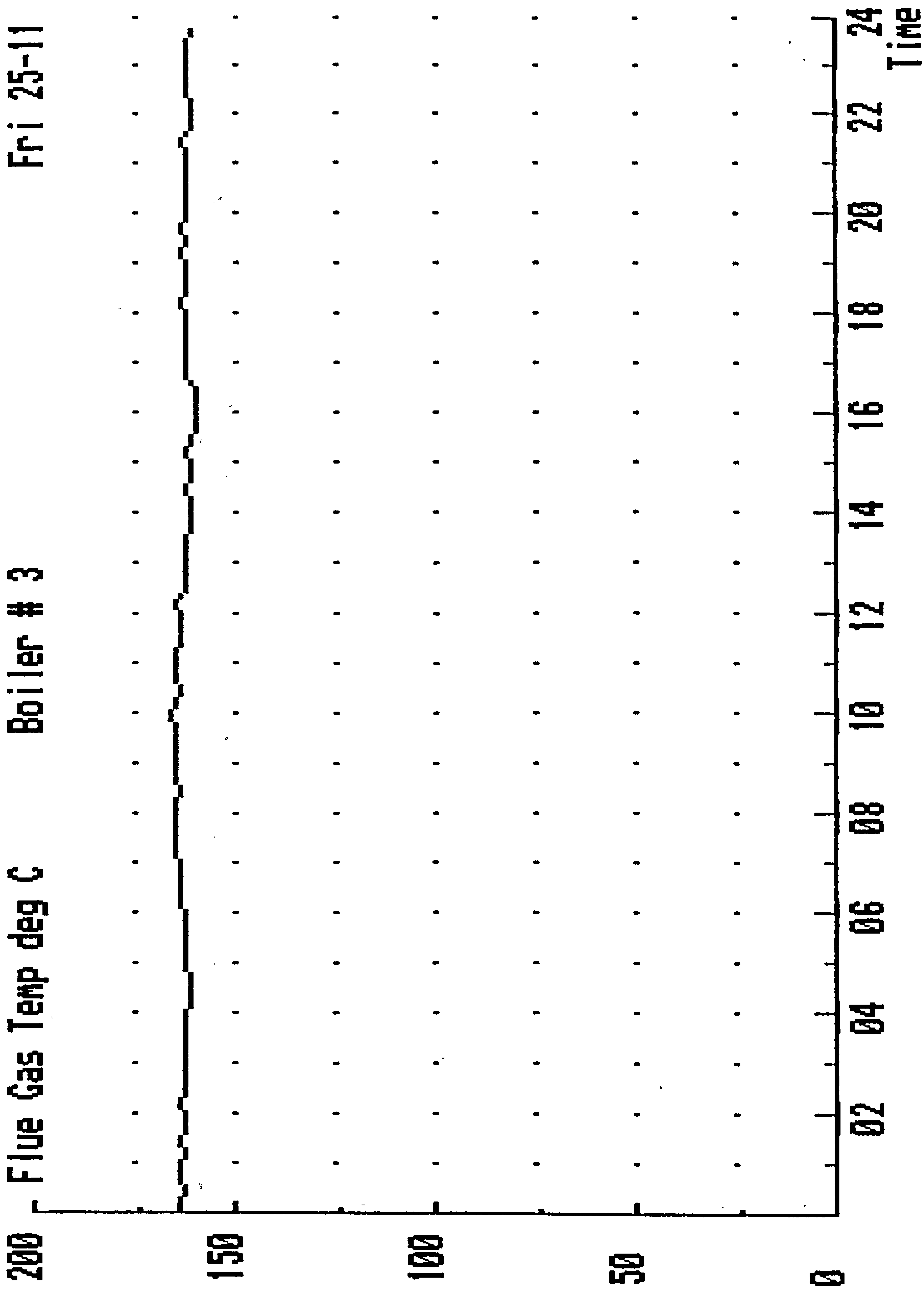

Flue Gas Temp deg C
Boiler # 3
Fri 25-11
200
150
100
50
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.8

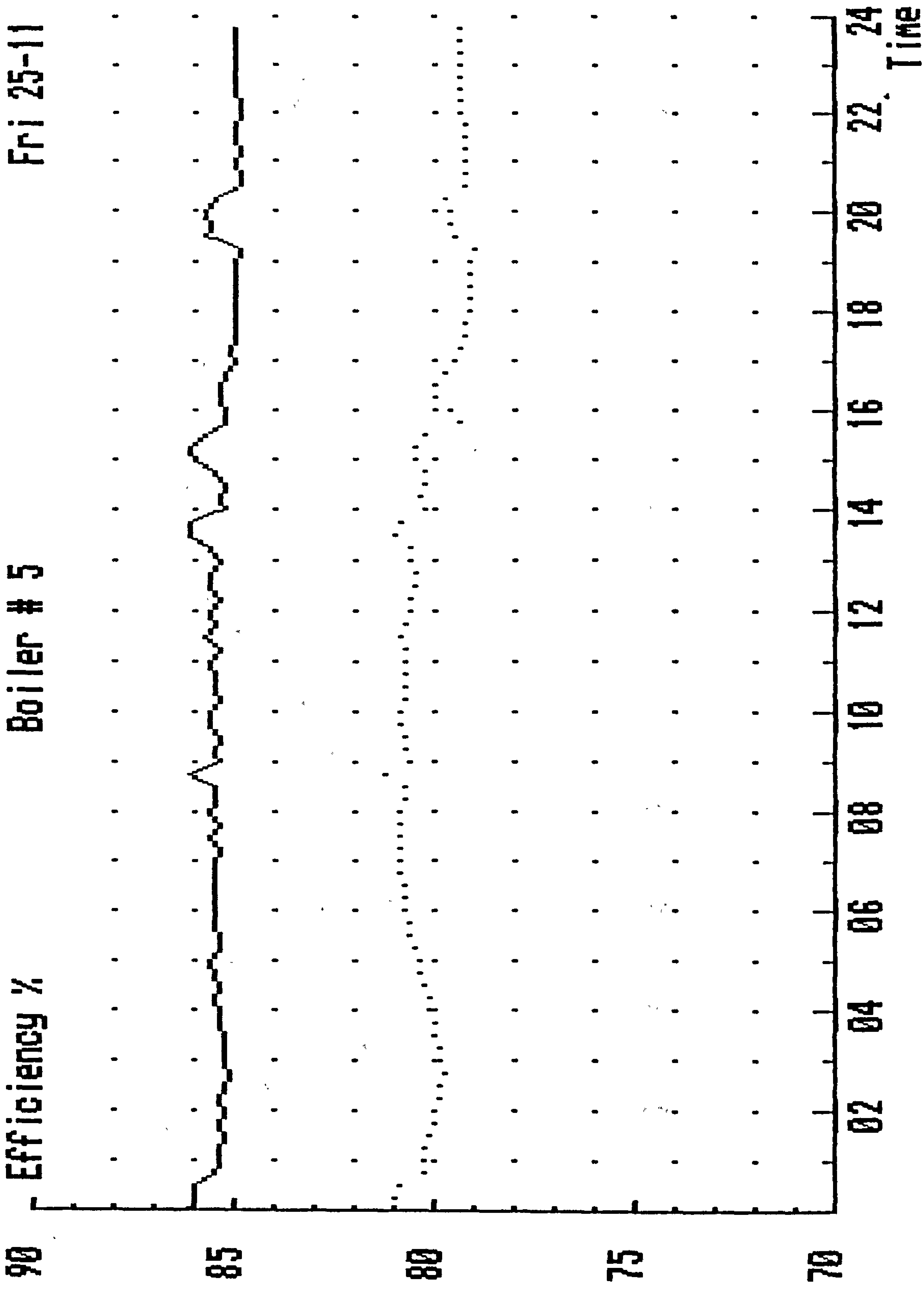

Efficiency %
Boiler # 5
Fri 25-11
90
85
80
75
70
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.9

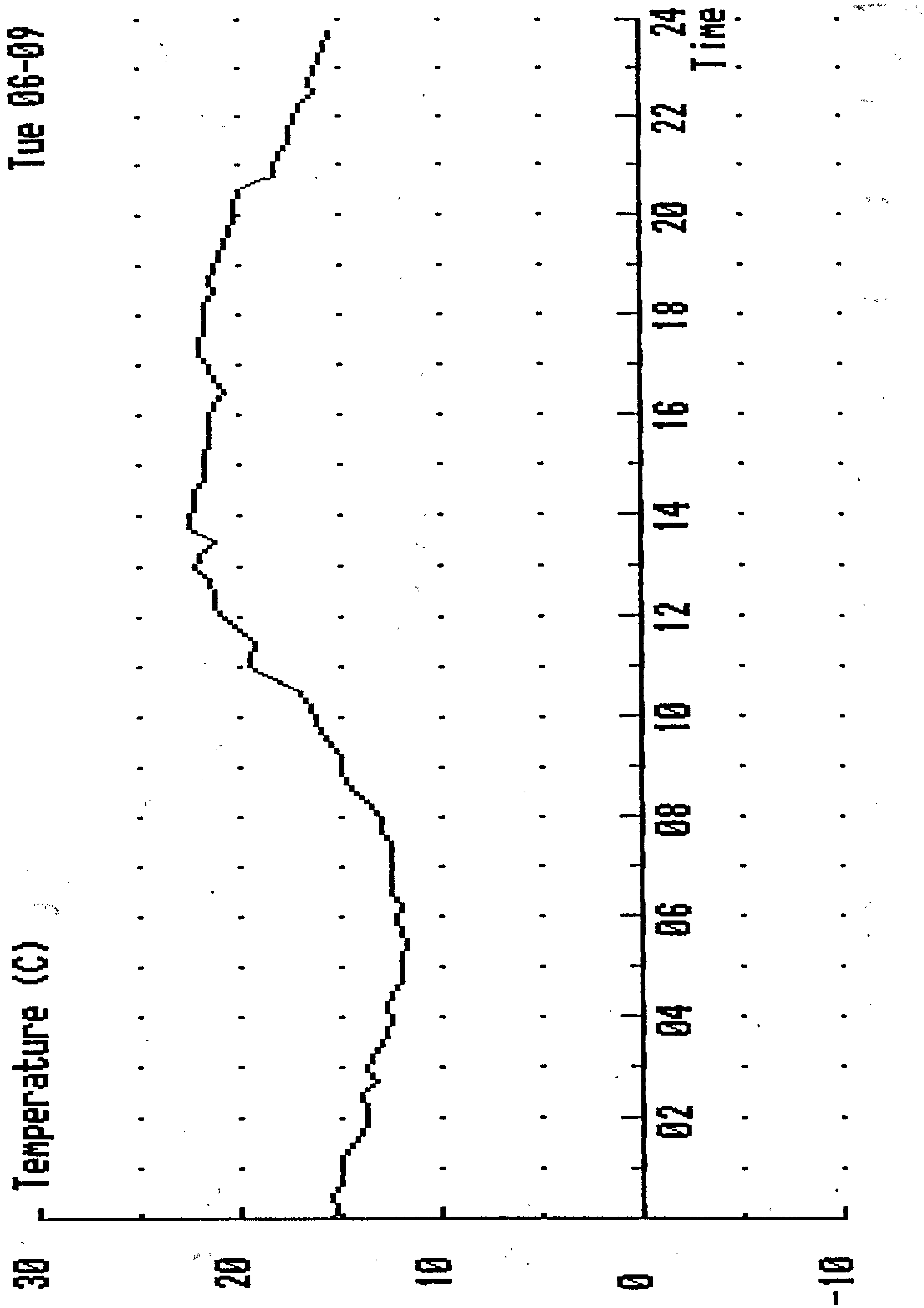

Tue 06-09
Temperature (C)
Time
30
20
10
0
-10
02
04
06
08
10
12
14
16
18
20
22
24

Fig. 6.10

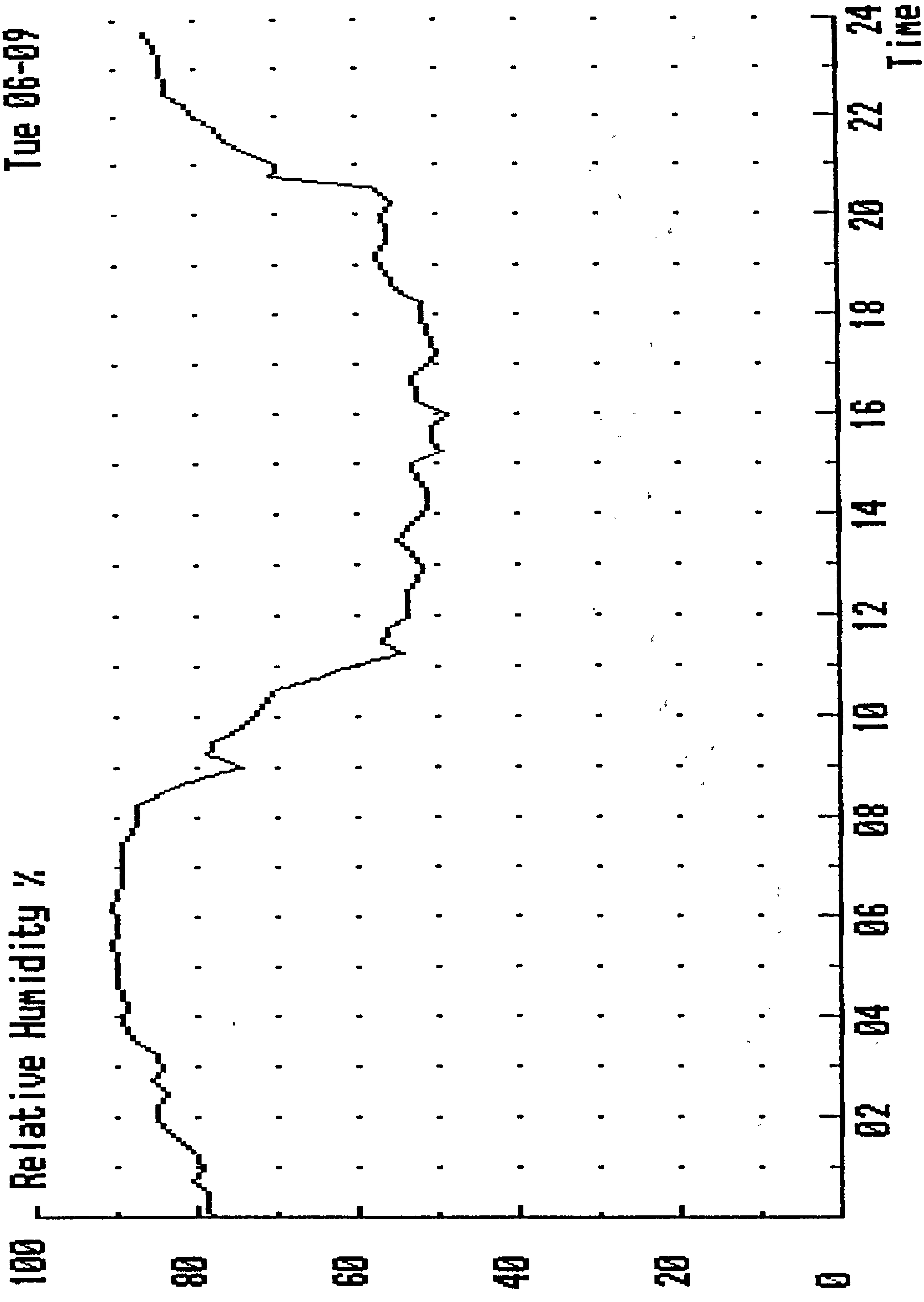

Relative Humidity %
Tue 06-09
Time
100
80
60
40
20
0
02
04
06
08
10
12
14
16
18
20
22
24

Fig. 6.11

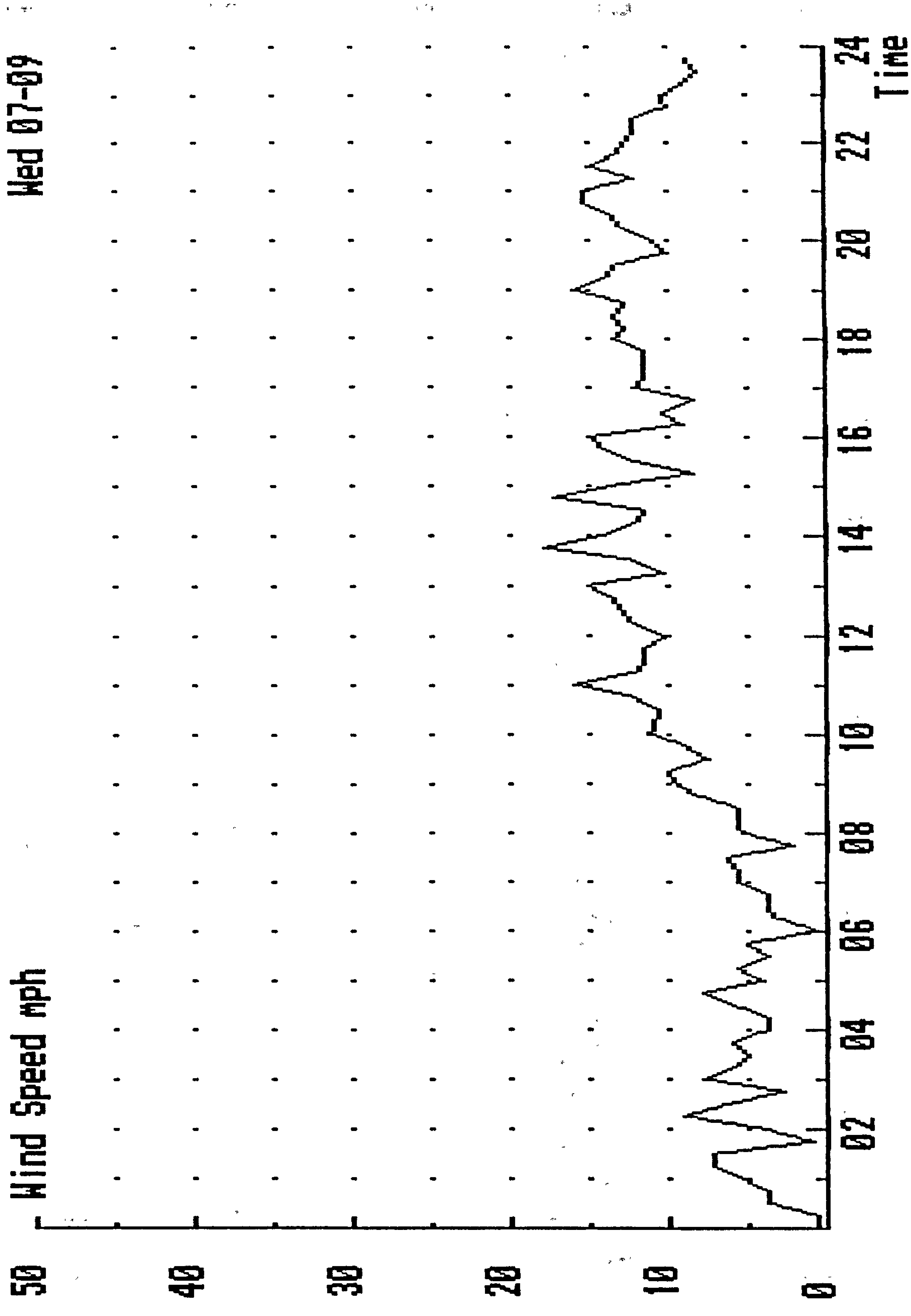

Wind Speed mph
Wed 07-09
Time
0
10
20
30
40
50
02
04
06
08
10
12
14
16
18
20
22
24

Fig. 6.12

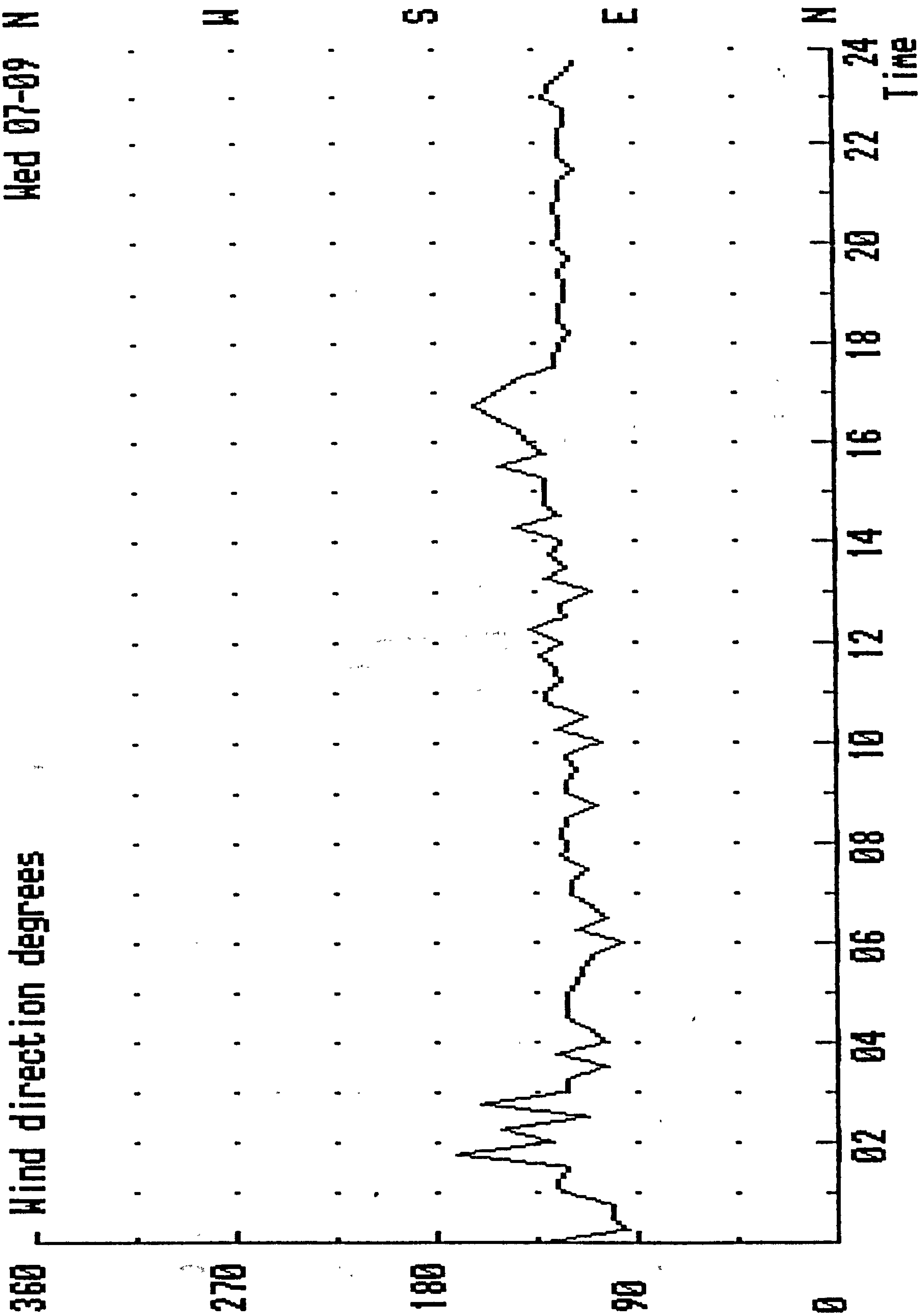

Wind direction degrees
Wed 07-09
N
W
S
E
N
360
270
180
90
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.13

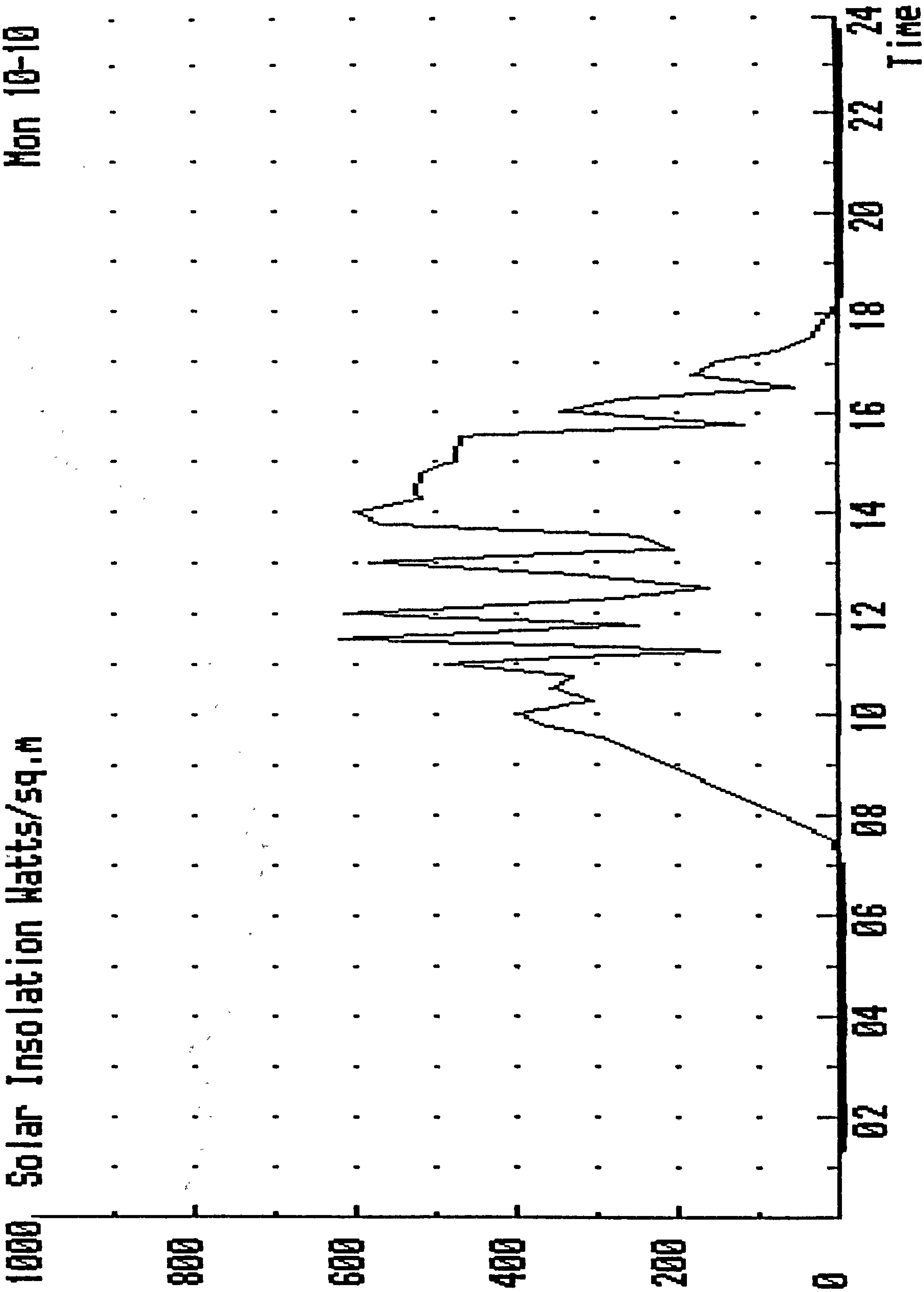

Solar Insolation Watts/sq.m
Mon 10-10
1000
800
600
400
200
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.14

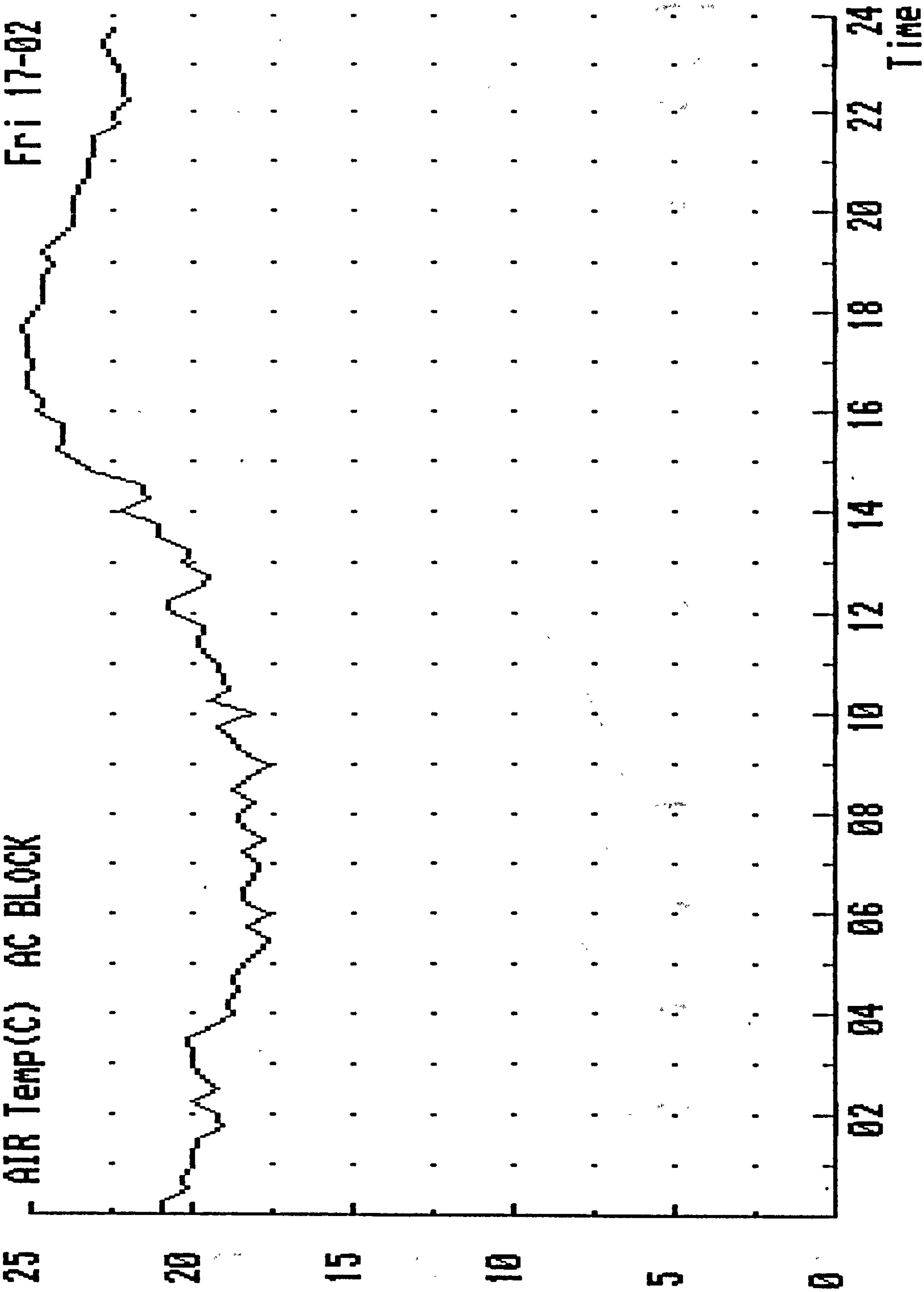

AIR Temp(C) AC BLOCK
Fri 17-02
25
20
15
10
5
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.15

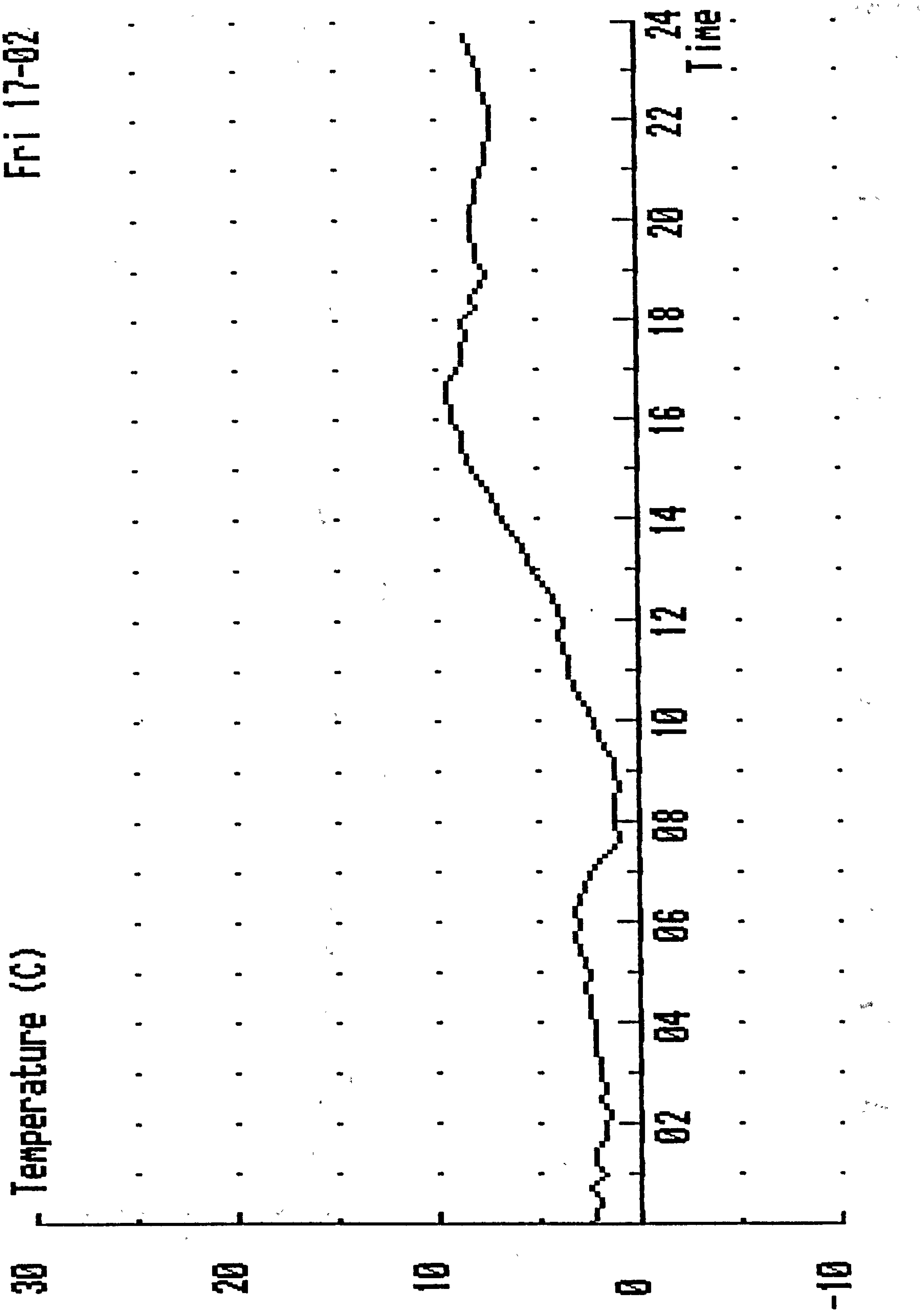

Fri 17-02
Temperature (C)
Time
00 02 04 06 08 10 12 14 16 18 20 22 24
30
20
10
0
-10

Fig. 6.16

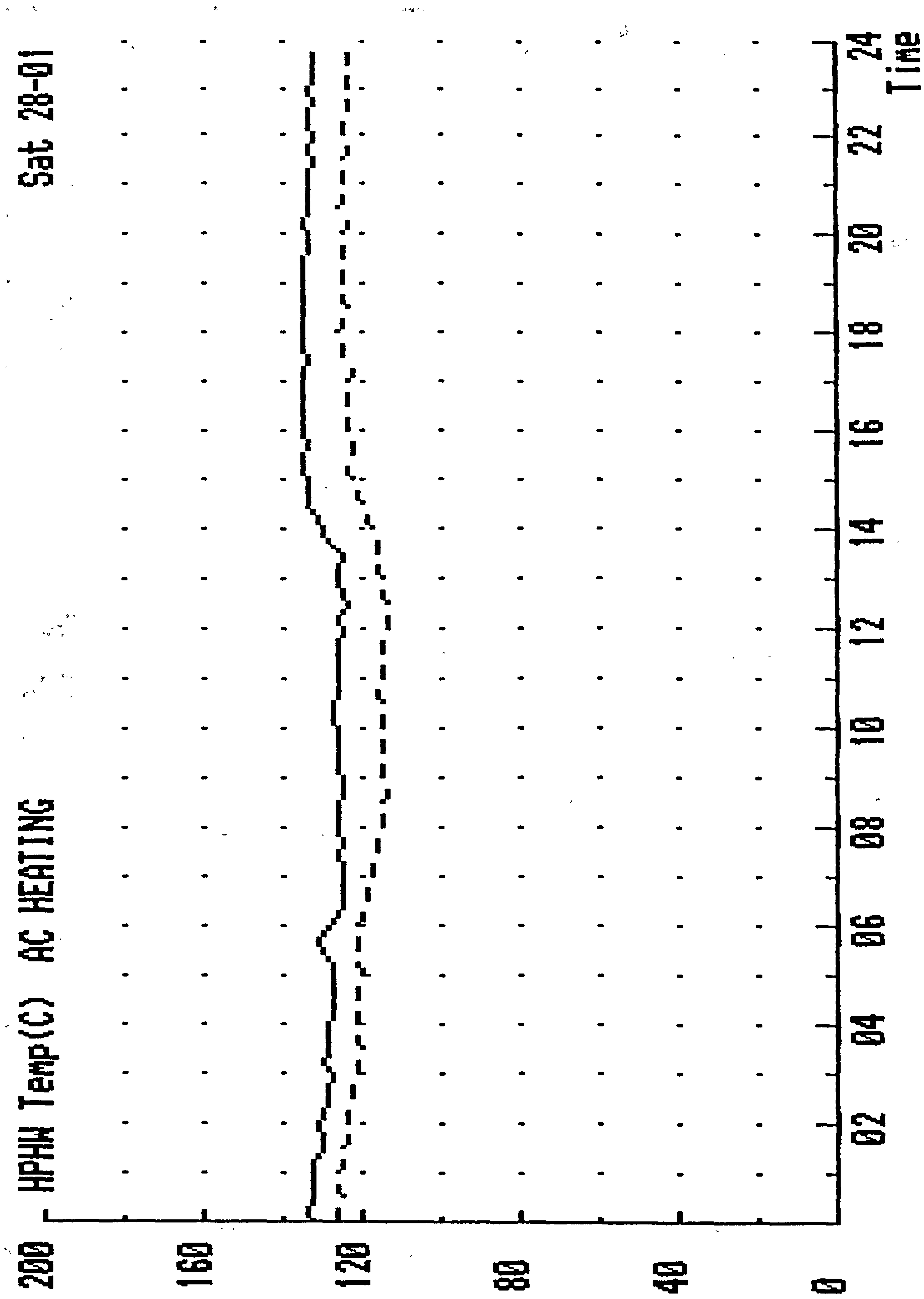

HPHW Temp(C) AC HEATING
Sat 28-01
200
160
120
80
40
0
02
04
06
08
10
12
14
16
18
20
22
24
Time

Fig. 6.17

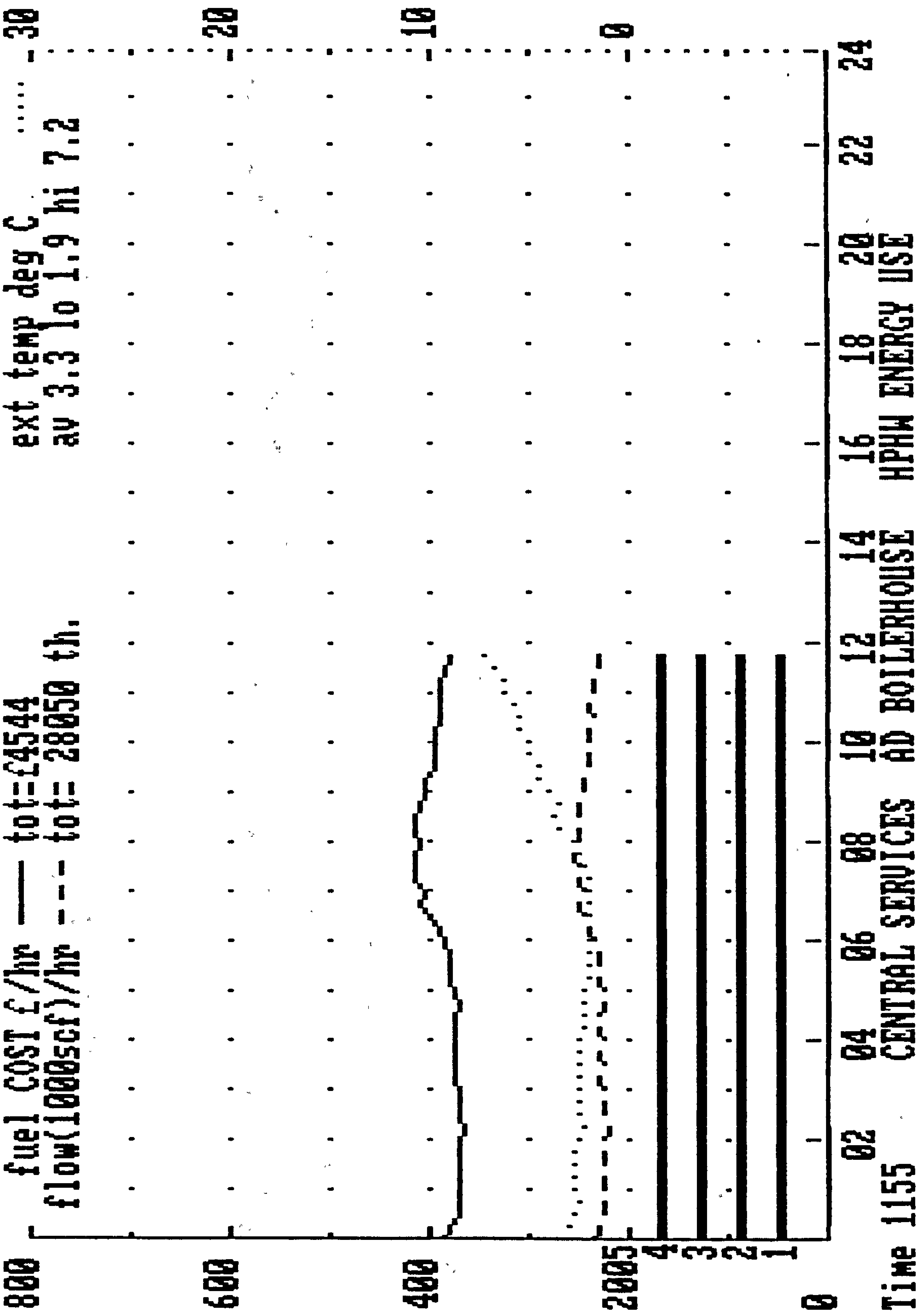

fuel COST £/hr —— tot=£4544
flow(1000scf)/hr - - - tot= 28050 th.
ext temp deg C .....
av 3.3 lo 1.9 hi 7.2
800
600
400
2005
0
4
3
2
1
30
20
10
0
02
04
06
08
10
12
14
16
18
20
22
24
Time 1155
CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig. 6.18

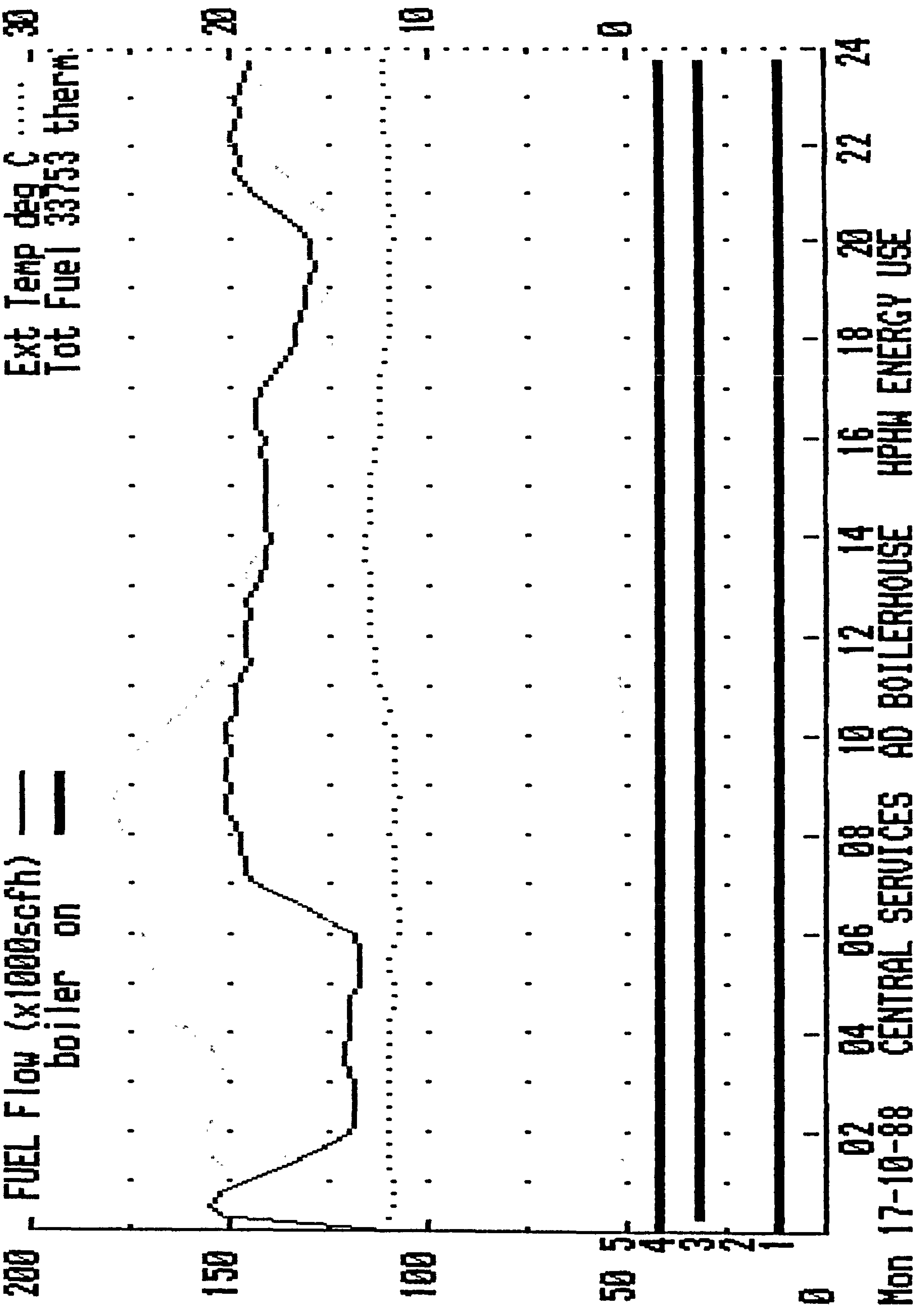

FUEL Flow (x1000scfh)
boiler on
Ext Temp deg C .....
Tot Fuel 33753 therm
200
150
100
50
5
4
3
2
1
0
30
20
10
0
Mon 17-10-88
02
04
06
08
10
12
14
16
18
20
22
24
CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig. 6.19

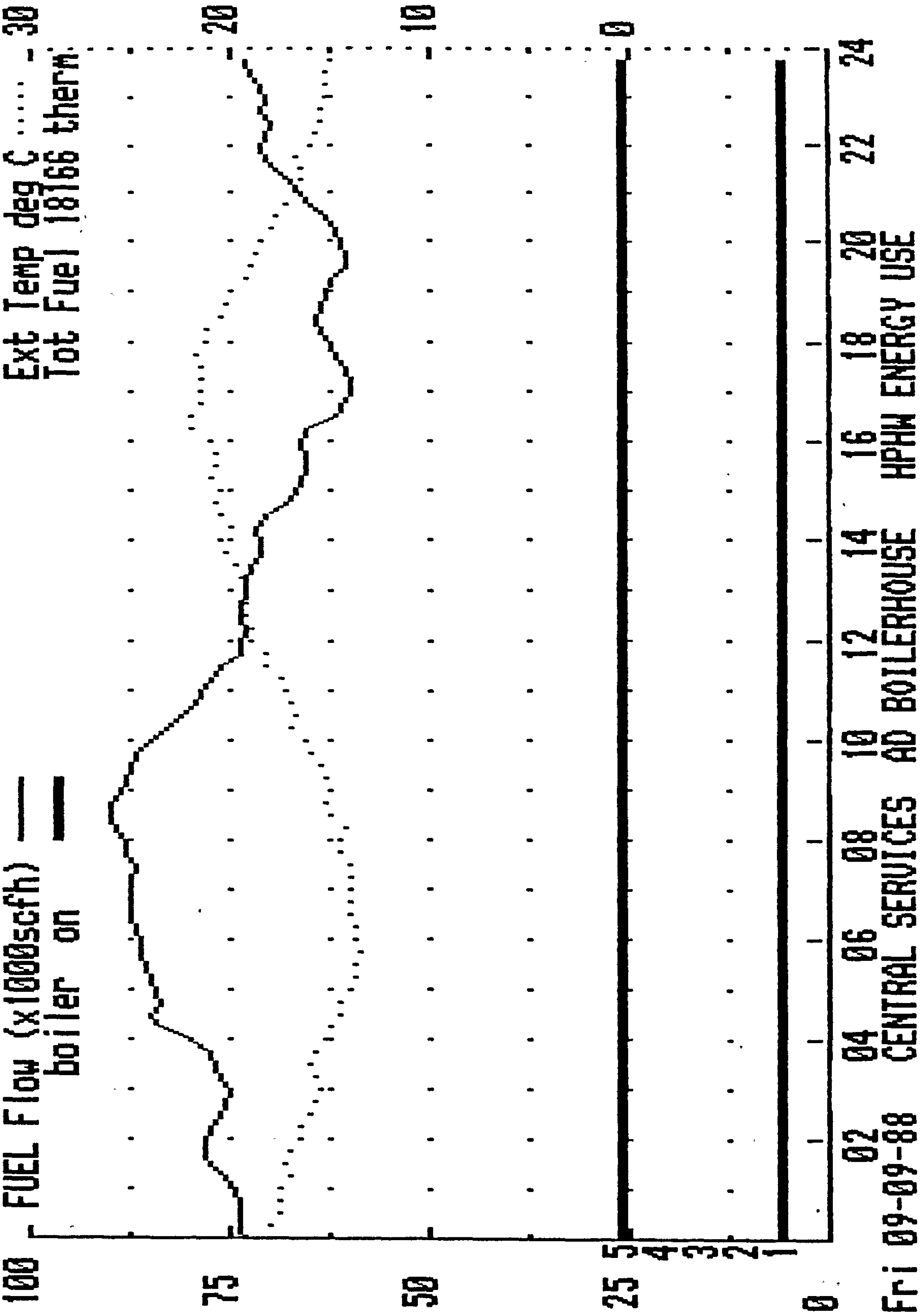

FUEL Flow (x1000scfh)
boiler on
Ext Temp deg C
Tot Fuel 18166 therm
100
75
50
25
0
30
20
10
0
5
4
3
2
1
02
04
06
08
10
12
14
16
18
20
22
24
Fri 09-09-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig. 6.20

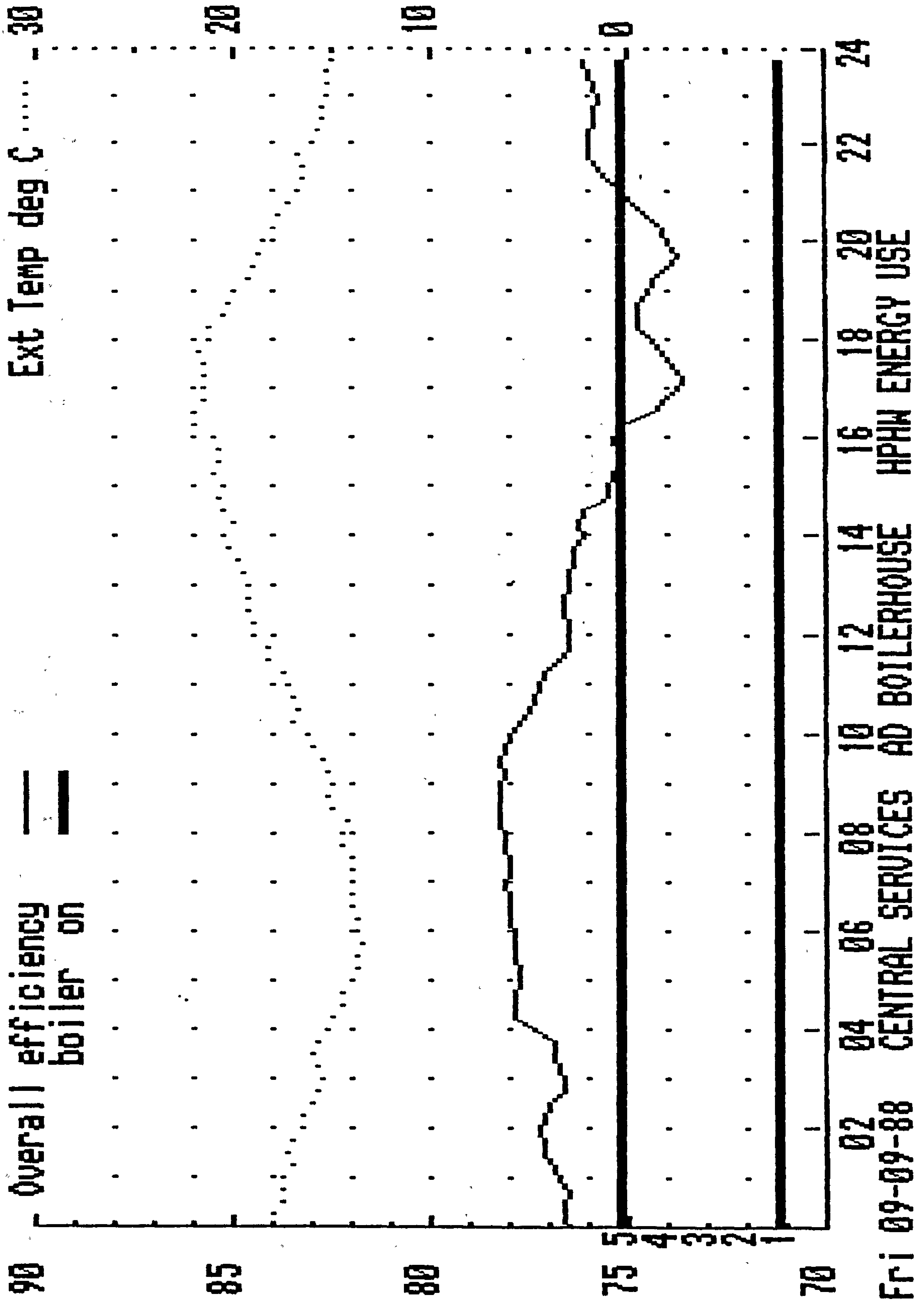

Overall efficiency
boiler on
Ext Temp deg C
90
85
80
75
70
30
20
10
0
5
4
3
2
1
02
04
06
08
10
12
14
16
18
20
22
24
Fri 09-09-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig.6.21

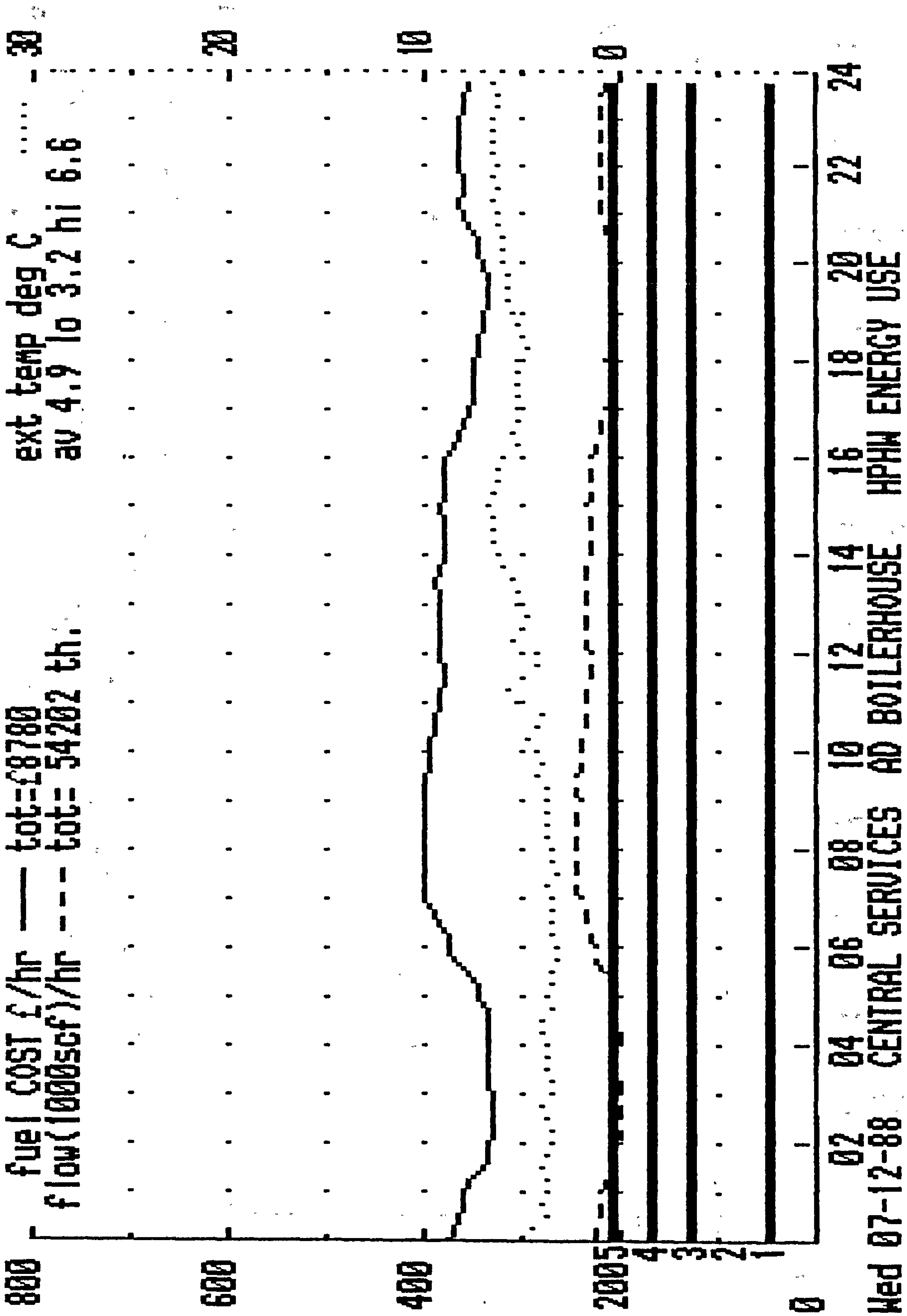

fuel COST £/hr —— tot=£8780
flow(1000scf)/hr - - - tot= 54202 th.
ext temp deg C .....
av 4.9 lo 3.2 hi 6.6
800
600
400
200
0
30
20
10
0
5
4
3
2
1
02 04 06 08 10 12 14 16 18 20 22 24
Wed 07-12-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig.6.22

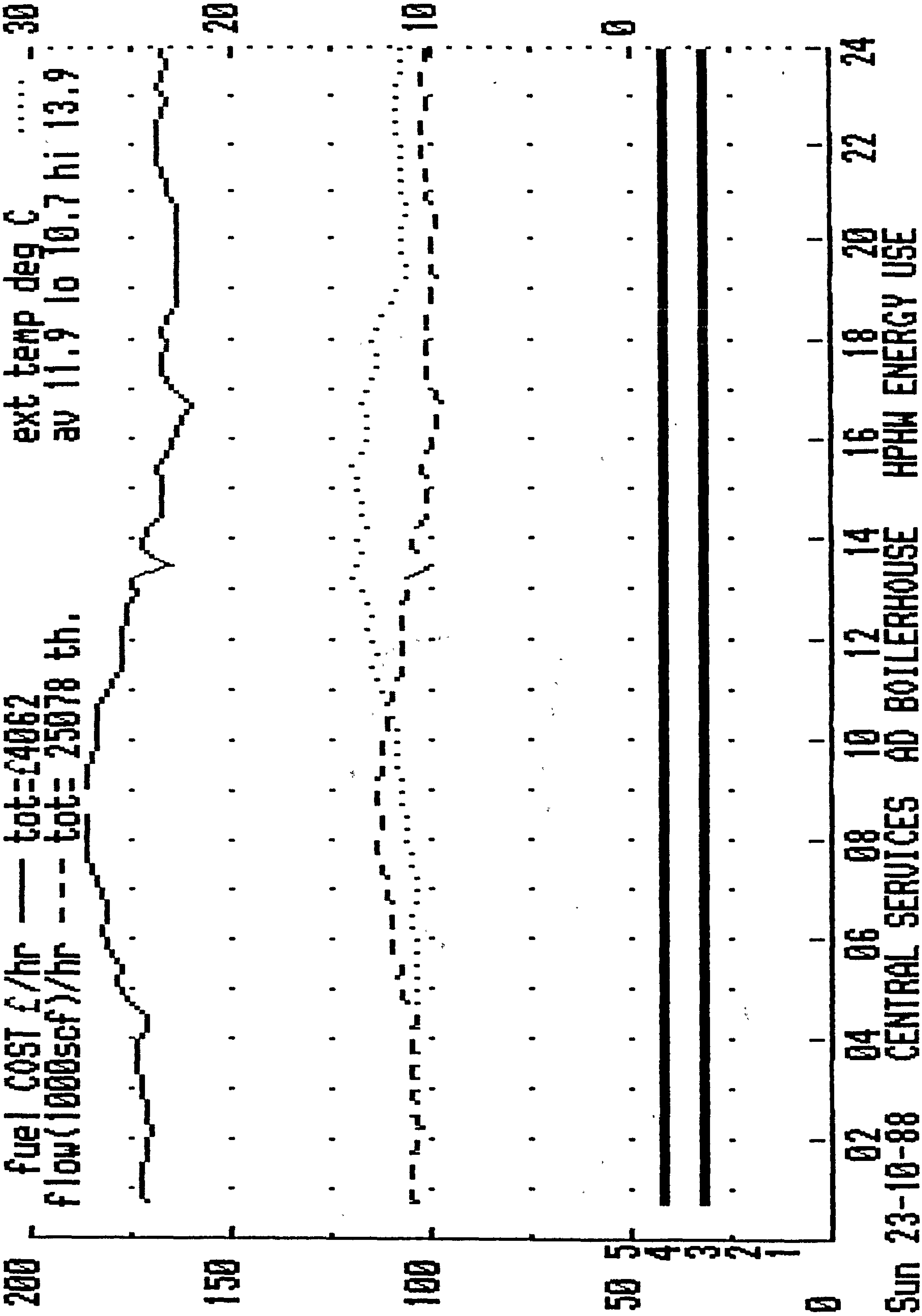

fuel COST £/hr —— tot=£4062
flow(1000scf)/hr - - - tot= 25078 th.
ext temp deg C .....
av 11.9 lo 10.7 hi 13.9
200
150
100
50
0
30
20
10
0
5
4
3
2
1
02
04
06
08
10
12
14
16
18
20
22
24
Sun 23-10-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig. 6.23

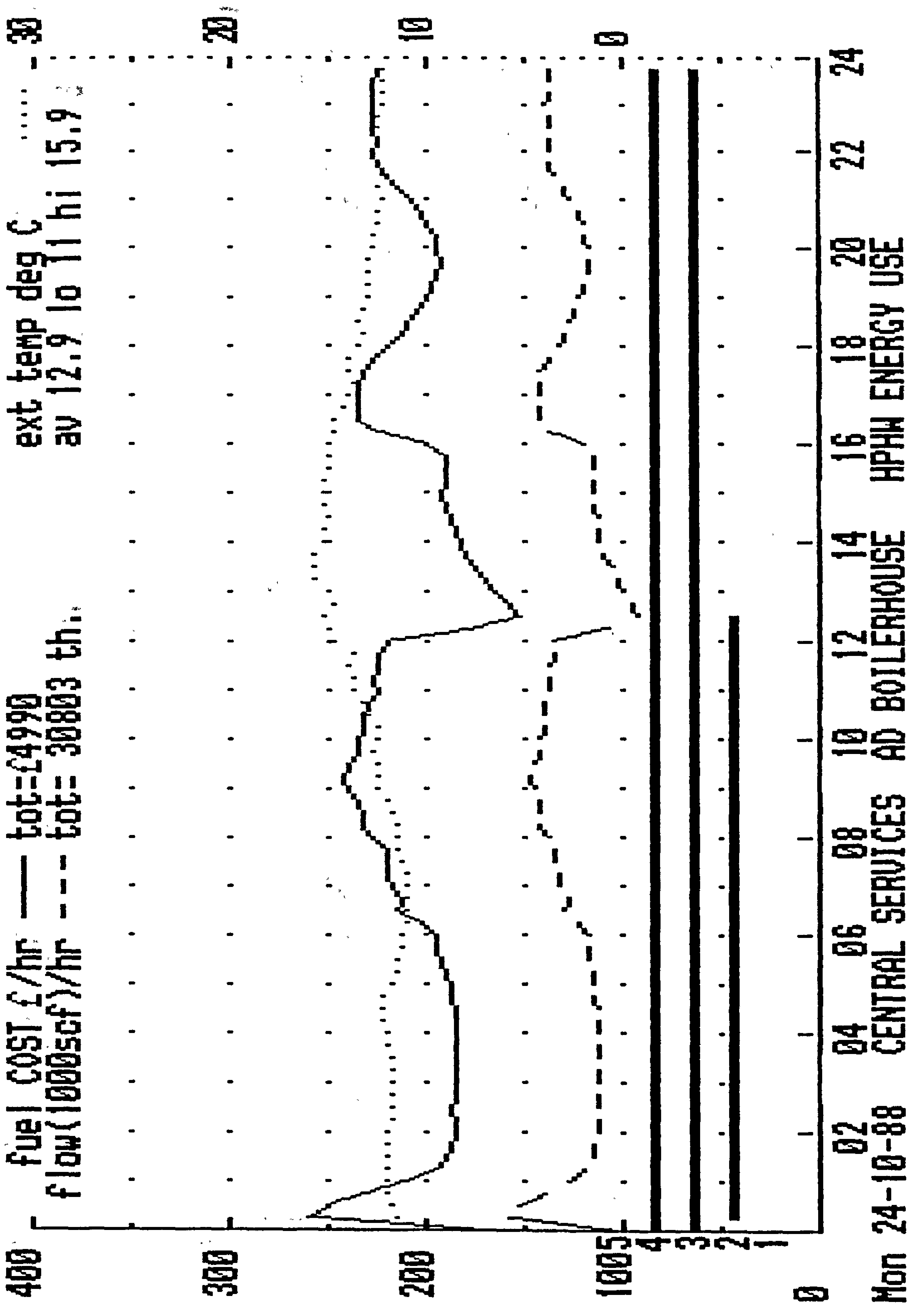

fuel COST £/hr —— tot=£4990
flow(1000scf)/hr - - - tot= 30803 th.
ext temp deg C .....
av 12.9 lo 11 hi 15.9
400
300
200
1005
0
30
20
10
0
4
3
2
1
02 04 06 08 10 12 14 16 18 20 22 24
Mon 24-10-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig.6.24

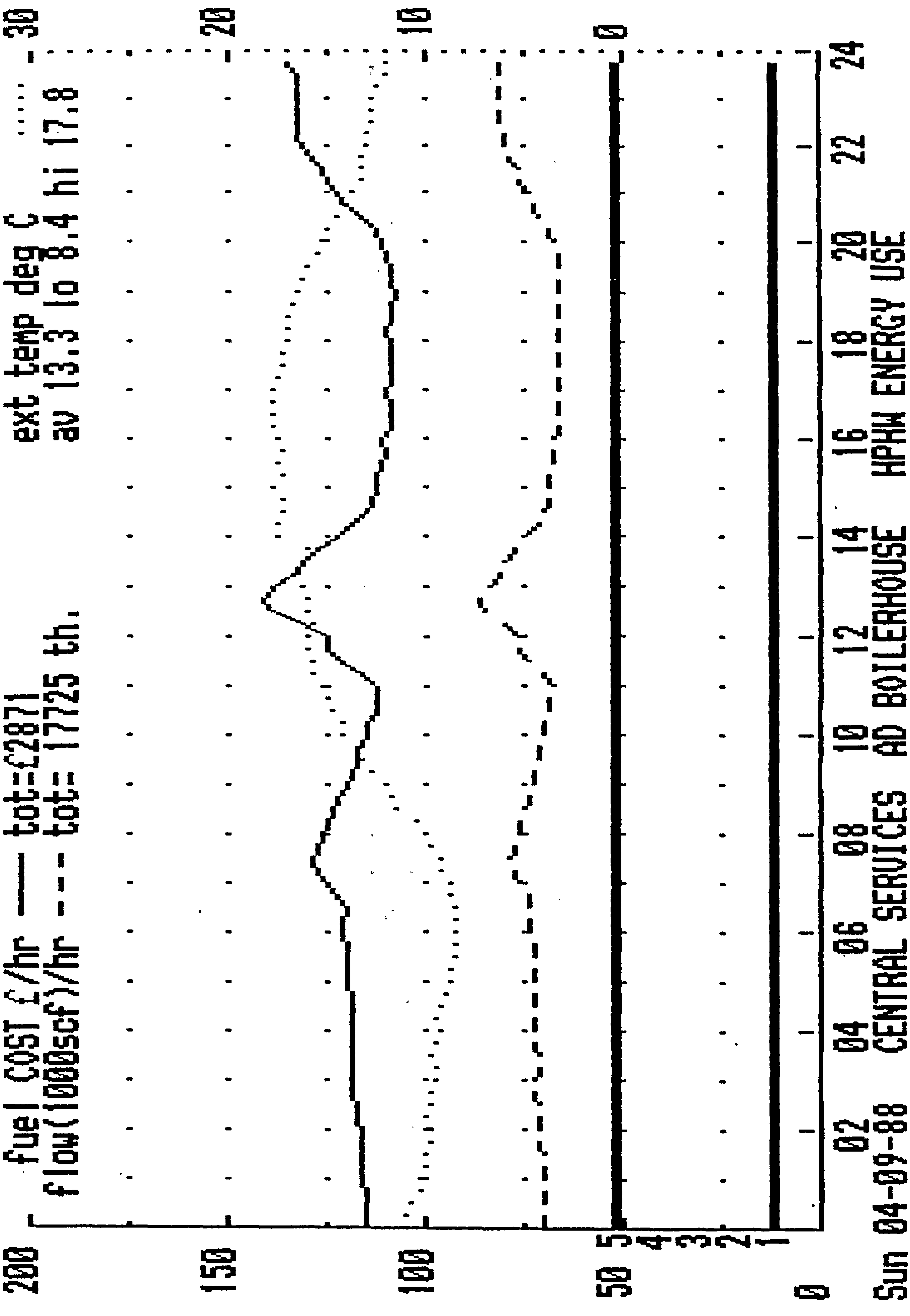

fuel COST £/hr —— tot=£2871
flow(1000scf)/hr - - - tot= 17725 th.
ext temp deg C .....
av 13.3 lo 8.4 hi 17.8
200
150
100
50
0
5
4
3
2
1
30
20
10
0
02
04
06
08
10
12
14
16
18
20
22
24
Sun 04-09-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig. 6.25

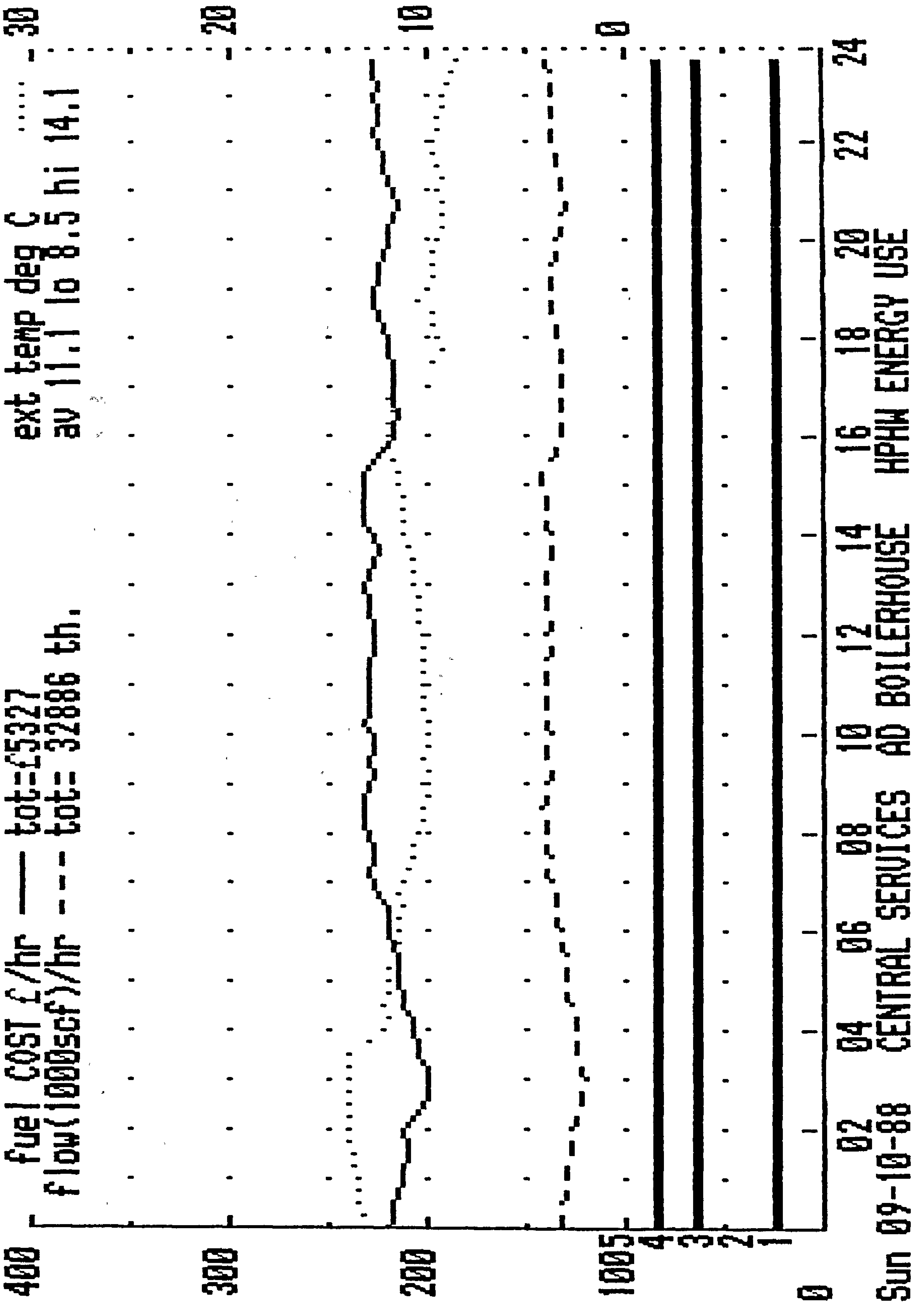
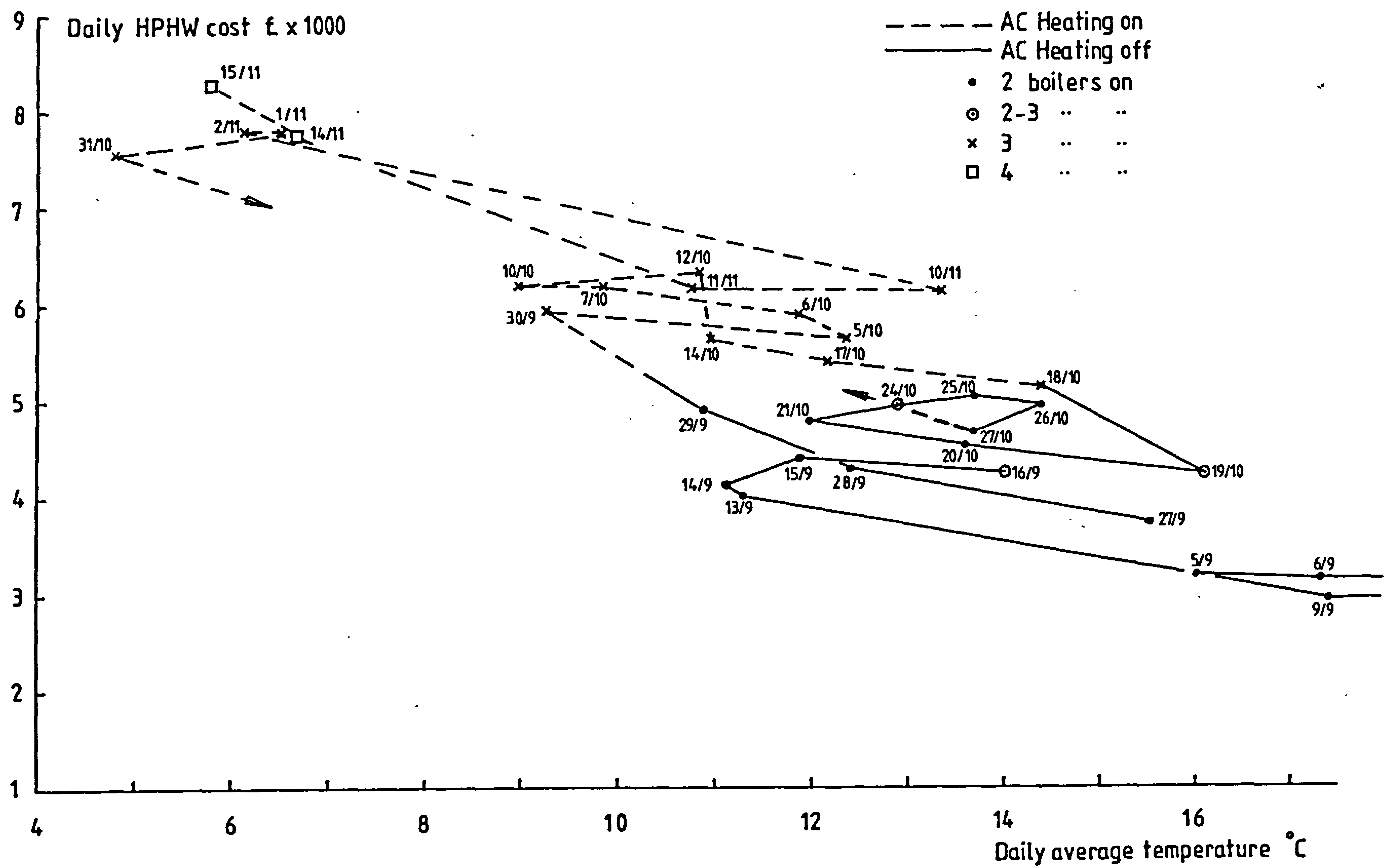

fuel COST £/hr —— tot=£5327
flow(1000scf)/hr - - - tot= 32886 th.
ext temp deg C ....
av 11.1 lo 8.5 hi 14.1
400
300
200
100
0
30
20
10
0
02 04 06 08 10 12 14 16 18 20 22 24
Sun 09-10-88 CENTRAL SERVICES AD BOILERHOUSE HPHW ENERGY USE

Fig.6.26



Daily HPHW cost £ x 1000
AC Heating on
AC Heating off
2 boilers on
2-3 .. ..
3 .. ..
4 .. ..
15/11
1/11
2/11
14/11
31/10
10/10
12/10
11/11
10/11
7/10
6/10
30/9
5/10
14/10
17/10
18/10
24/10
25/10
21/10
26/10
29/9
27/10
20/10
19/10
15/9
16/9
14/9
28/9
13/9
27/9
5/9
6/9
9/9
Daily average temperature °C

Fig. 6.27

AD HPHW Model Calculations for Friday 27 Jan 1989

		PROCESS	HEATING	BOILER	
TEMPS	ASSUMED	169.2	149.3	175.1	

FLOWS	:CALCULATED	PROCESS	HEATING	TOTAL	:OBSERVED
THROUGH	BOILERS	2446000	532000	2979000	2965000
		175.1	175.1		
THROUGH	MIXING	903000 (26%)	1297000 (70%)	2200000	
		153.2	138.7		
TO	FACTORY	3350000	1830000	5180000	
	flow	169.2	149.3		
	return	153.2	138.7	150.6	150.75
HEAT	MBTU/HR	96	35	131	130

NO.OF BOILERS FOR HEAT	(70MBTU/HR EACH)	1.8
NO.OF BOILERS FOR FLOW	(800,000LB/HR EACH)	3.7

Fig. 6.28

AD HPHW Model Calculations for Possible flow modifications

	PROCESS	HEATING	BOILER	
TEMPS ASSUMED	169.2	149.3	180	

FLOWS :CALCULATED	PROCESS	HEATING	TOTAL	:OBSERVED
THROUGH BOILERS	1999000 180	469000 180	2468000	2965000
THROUGH MIXING	1350000 (40%) 153.2	1360000 (74%) 138.7	2711000	
TO FACTORY	3350000	1830000	5180000	
flow	169.2	149.3		
return	153.2	138.7	150.5	150.75
HEAT MBTU/HR	96	35	131	130

NO.OF BOILERS FOR HEAT	(70MBTU/HR EACH)	1.8
NO.OF BOILERS FOR FLOW	(800,000LB/HR EACH)	3

Fig. 6.29

CHAPTER 7

CONCLUSIONS

The conclusions are drawn on the basis of work conducted at a single industrial plant, which was chosen at random, but it is considered that they would be relevant to other similar plants.

7.1 General Observations

The following observations of a general nature are considered relevant to the work in this thesis.

* The 'laissez-faire' attitude towards energy conservation, resource depletion and environmental degradation shown by recent government in the U.K. and the low priority attributed to conservation in industry by management have together produced an indifference towards energy consumption, leading to highly wasteful practises.

* Whilst the plant studied employs a number of processes critically dependent on the continuous supply of energy, the current low unit-cost of energy and the overwhelming importance of maintaining trouble-free production, together mitigate against attempts to improve the efficiency of supply of that energy by modifying operating procedures.

* Attitudes amongst operating staff may tend to further mitigate against change and hence the potential improvement of the energy efficiency of operations. These exist for two reasons viz: (i) A considerable body of 'pseudo-knowledge' exists, assumed sacrosanct, which has been followed for many years and (ii) operational changes generally involve increased vigilance and activity.

* The low priority attributed to the investigation of energy usage and conservation is apparent from the poorly maintained and inadequate instrumentation present. The maintenance of instrumentation poses a significant hurdle, both in terms of skilled manpower and planning, to overcome before any meaningful detailed analysis of energy use may be undertaken for the purposes of improving control.

7.2 Specific Observations

* A suite of programs has been developed (Chapter 3) to produce tabular and graphical analyses of energy usage for a large industrial plant employing several energy types. The data serves to heighten management awareness of energy flows and the relative

contributions from each energy type towards the total annual consumption and cost.

* The general analysis described (Chapter 4) has enabled several significant opportunities for energy conservation, by modifying operating procedures, to be identified which amount to some 5% of the total annual energy bill at the plant studied. This general approach is considered as a first step towards energy conservation in a large industrial plant whereby management are repeatedly reminded, by way of graphically oriented, easily assimilated reports, of practises leading to energy wastage.

* Several recommendations deduced from the general analysis at the plant studied have been implemented (section 4.9).

* Data required for such a general analysis is easily transferred over the PSTN and this facility enables a central agency to monitor the performance for a number of plants and produce regular analyses of energy usage.

* The general analysis has also enabled a number of areas to be identified which may benefit from more detailed analyses. One important area has been the centralised boilerhouse which supplies the plant with high pressure hot water.

* A monitoring and targeting system to enable a detailed energy analysis of the centralised boilerhouse has been developed (Chapter 5). Hardware has been installed and software written to enable an integrated system to collect data via hard-wiring and radio telemetry which monitors and logs boiler, environmental and plant parameters in real time.

* Radio telemetry data acquisition equipment has been demonstrated as a reliable alternative to hard-wiring for the purposes of energy monitoring.

* A detailed analysis of the energy used by the boilerhouse is carried out (Chapter 6) and data gathered over a period of six months enables (i) specific cases of energy wastage resulting from operational procedures to be identified and (ii) trends of performance indicating poor energy efficiency to be traced. Examples have illustrated how the monitoring system may be used to establish targets of energy use to be aimed at to reduce energy usage. A detailed analysis is considered a second step towards energy conservation.

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REFERENCES

Advantech, 1987. Advantech Co. Ltd. IEEE 488 Bus Controller for the IBM PC. Data Design Techniques. Welwyn Garden City. Herts. UK. 1987.

Allen, 1986. Allen, E.J. Comparing the predictions of building thermal performance calculations - an assessment of the technique illustrated for a typical U.K. dwelling. Building Research Establishment. Watford. U.K.. 1986.

Amman, 1981. Amman, F. and R. Wilson (Editors). Energy Demand and Efficient Use - Proceedings of the Fourth International School on Energetics, 1980, Erice, Sicily. Plenum Press. New York. USA. 1981.

Bell, 1987. Bell, C.R. and B.D. Neve. Process Plant Telemetry by Radio. Sensor Review, October, Vol. 7 No. 4, 1987.

Bickle, 1983. Bickle, L. Retrofitting of Commercial Institutional and Industrial Buildings for Energy Conservation. (Editor Meckler, M.). Van Nostrand. New York. USA. 1984.

Bloomfield, 1985. Bloomfield, D. Appraisal Techniques for methods of calculating the thermal performance of buildings. Building Services Engineering Research and Technology. No 1 Vol 6. 1985.

Borland, 1987. Borland International. Turbo Basic. Borland. Scotts Valley. Calif. USA. 1987.

Brinkworth, 1972. Brinkworth, B.J. Solar Energy for Man. The Compton Press. Salisbury, U.K.. 1972.

British Petroleum, 1982. British Petroleum Statistical Review of World Energy 1981. British Petroleum Company, London, 1982.

BS, 1972. British Standards Institution. Acceptance tests for industrial steam boilers and steam generators. BS 845. British Standards Institution. London. 1972.

BS, 1974. British Standards Institution. Acceptance tests on stationary steam generators of the power station type. BS 2885. British Standards Institution. London. 1974

Burr-Brown, 1988. Burr-Brown. The Handbook of Personal Computer Instrumentation. Burr-Brown Corporation. Tucson. Arizona. USA. 1988.

Carter, 1985. Carter, J. Energy Policy. April, 1985.

Chandran, 1986. Chandran, S. Presidential Address to the 13th World Energy Conference. World Energy Conference, Annual Report 1986. World Energy Conference. London. 1987.

Chase, 1986. Chase Econometrics. The next oil shock: a planning guide for world energy markets, 1986 - 2000. Chase Econometrics. New York. USA.

Clark, 1982. Clark, W.C. (Editor), Carbon Dioxide Review: 1982. Oxford University Press. New York. 1982.

Conf. Use of Solar Energy, 1955. Transactions of the Conference on the Use of Solar Energy. Vols 2 and 3. Tucson, Arizona. 1955.

Daniels, 1954. Daniels and Duffie. Solar Energy Research. 1954.

Davis, 1987. Davis, M. Energy - European Year of the Environment plus Fifty Conference. Proceedings. Tynemouth, U.K.. 1987.

Delorme, 1980. Delorme, Y., L. Laret and H. Sohet. Numerical predictions of thermal behaviour in dwelling structures. University of Liege. Liege. Belgium. 1980.

DOE, 1982. Armitage Norton Consultants. Energy Conservation Investment in Industry - Energy Paper No 50. Department of Energy. London. 1982.

DOE, 1985. Government Statistical Service. United Kingdom Energy Statistics 1985. Department of Energy. London. 1985.

DOE, 1987(a). Government Statistical Service. United Kingdom Energy Statistics 1987. Department of Energy. London. 1987.

DOE, 1987(b). Government Statistical Service. Energy Flow Chart 1986 United Kingdom. Department of Energy. London. 1987.

DOE, 1988. Private communication. Department of Energy. London. 1988.

DTI, 1988. Department of Trade and Industry. Industrial Energy Thrift Scheme Reports. Department of Trade and Industry. London.

Dunn, 1986. Dunn, P.D. Renewable Energies. Peregrinus. London. 1986

EEO, 1985(a). Energy Efficiency Office. Grants for short energy efficiency surveys. EEO. Department of Energy. London. U.K.. 1985.

EEO, 1985(b). Energy Efficiency Office. Grants for extended energy efficiency surveys. EEO. Department of Energy. London. U.K.. 1985.

EEO, 1986(a). Energy Efficiency Office. A first step to energy efficiency. EEO. Department of Energy. London. U.K.. 1986.

EEO, 1986(b). Energy Efficiency Office. Financial assistance for demonstrating the efficient use of energy. EEO. Department of Energy. London. U.K.. 1986.

EEO. 1986(c). Energy Efficiency Office. Monitoring and Targeting for Energy Efficiency. EEO. Department of Energy. London. U.K.. 1986.

EEO, 1987. Energy Efficiency Office. Expanded Project Profile 31 - Energy Management in medium sized industrial sites. EEO. Department of Energy. London. U.K.. 1987.

Energy Information Centre, 1987. Fuels Purchasing 1987. Energy Information Centre. Energy Publications. Cambridge. U.K.

ETSU, 1986. Energy Technology Support Unit. Energy Management Systems. Energy Technology Series 1. ETSU. Harwell. U.K. 1986.

Fells, 1987(a). Fells, I. Energy - to have and have not. Energy World. No 143. 1987.

Fells, 1987(b). Fells, I., J. Swithenbank and A. Williams. The potential for energy conservation in developed and developing countries. Energy World. No 145. 1987.

Ferraro, 1983. Ferraro, R., R. Godoy and D. Turrent. Monitoring Solar Heating Systems. Pergamon Press. Oxford. U.K.. 1983.

FOE, 1988. Friends of the Earth. Independent scientific study on the effects of acid rain. Friends of the Earth Ltd. London. 1988.

Frisch, 1983. Frisch, J.R. (Editor). World Energy Conference, Energy 2000 - 2020: World Prospects and Regional Stresses. Graham and Trotman. London. 1983.

Golding, 1949. Golding and Stodhart. E.R.A. Report No. W/T16. Electrical Research Association. Leatherhead, U.K.. 1949.

Hale, 1979. Hale, D. et al. The Industrial Energy Thrift Scheme - Aims, results and achievments. Energy for Industry. (Ed. O'Callaghan, P). Pergamon Press. Oxford. U.K..1979.

Hafele, 1981. Hafele, W. et al. Energy in a Finite World - A Global Systems Analysis. Ballinger. Cambridge, Mass..1983.

HMSO, 1967. Fuel Policy. Her Majesty's Stationery Office. 1967.

HMSO, 1984. Energy Efficiency Office. Fuel Efficiency Booklet Series Nos 1 - 18. HMSO. London. 1984.

Holdren, 1986. Holdren, J.P. Earth and The Human Future. Editors K.R. Smith et al. Westview Press. Boulder. Colorado. 1986.

Holdren, 1987. Holdren, J.P. Global environmental issues related to energy supply: The environmental case for increased efficiency of energy use. Energy Vol 12 No 10/11 1987.

Holmes, 1986. Holmes, M.J. What's a dynamic thermal model. Building Services. March, 1986.

Inst. En., 1986. The Institute of Energy. Energy for the Future. The Institute of Energy. London. 1986.

Inst. Mech. Eng., 1988. Engineering News. No 35. January, 1988. The Institution of Mechanical Engineers. London.

Interpod, 1986. Interpod operating information. Meadmore Electronics. Netherton. Merseyside. U.K.. 1986.

Johansson, 1987. Johansson, T.B. and R.H. Williams. Energy Conservation in the Global Context. Energy. Vol 12 No 10/11 1987.

Keyfitz, 1977. Keyfitz, N. Population of the world and its regions, 1975 - 2050. International Institute for Applied Systems Analysis. Report WP-77-7. Laxenburg. Austria. 1977.

Maples, 1981. Maples, G. and D.F. Dyer. Boiler Efficiency Improvement. Boiler Efficiency Institute. Auburn. Alabama. USA. 1981.

Meckler, 1984. Meckler, M. (Editor) Retrofitting of commercial, institutional and industrial buildings for energy conservation. Van Nostrand. New York. 1984.

Metrabyte, 1988. Metrabyte. Data Acquisition and Control. Metrabyte Corporation. Taunton. Maryland. USA. 1988.

Microsoft, 1987(a). Microsoft Corporation. Microsoft QuickBasic Version 3. Microsoft Corporation. Reading. Berks. UK. 1987

Microsoft, 1987(b). Microsoft Corporation. Microsoft Windows Version 2. Microsoft Corporation. Reading. Berks. UK. 1987.

National Academy of Sciences, 1980. Committee on Lead in the Human Environment, National Academy of Sciences. Lead in the Human Environment. National Academy Press, Washington, D.C.. 1980

National Research Council, 1981. Committee on the Atmosphere and the Biosphere, National Research Council. Atmosphere - Biosphere Interactions. National Academy Press. Washington, D.C.. 1981.

NIFES, 1984. National Industrial Fuel Efficiency Service. The Buisnessman's Energy Directory. Formecon Publishing. U.K.. 1984.

Norton, 1987. Norton, B. Energy Management. August 1987. Department of Energy. London. 1987.

O'Callaghan, 1979. O'Callaghan, P. (Editor) Energy for Industry. Pergamon Press. Oxford. U.K.. 1979.

O'Keefe, 1987. O'Keefe, P. Energy - European Year of the Environment plus Fifty Conference. Proceedings. Tynemouth, U.K.. 1987.

Osborn, 1985. Osborn, P. Handbook of Energy Data and Calculations. Butterworths. London. 1985.

Payne, 1980. Payne, G. The Energy Managers' Handbook. IPC Science and Technology Press. Guildford. UK. 1980.

Princiotta, 1988. Princiotta, F. Procs. of The Clean Coal Conference. Institution of Mechanical Engineers. London. 1988.

Probert, 1987. Probert, S. D. U.K. Governments' Energy Policies. Applied Energy. Vol 28 No 3. 1987.

Proc. World Symposium, 1955. Proceedings of the World Symposium on Applied Solar Energy. Phoenix, Arizona. 1955.

Reay, 1977. Reay, D. Industrial Energy Conservation. Pergamon Press. Oxford. U.K.. 1977.

Ross, 1987. Ross, M., E.D. Larson and R.H. Williams. Energy demand and materials flow in the economy. Energy Vol 12 No 10/11. 1987.

Sassone, 1984. Sassone, P. and M. Martucci. Industrial energy conservation: the reasons behind the decisions. Energy Vol 9 No 4. 1984.

Satchwell, 1986. Satchwell Control Systems Ltd. BAS 700 Series 3 Building Management System. Satchwell Ltd. Slough. Berks. U.K.. 1986.

SCEP, 1970. SCEP Group. Report on the Study of Critical Environmental Problems - Man's Impact on the Global Environment - Assessments and Recommendations for Action. The M.I.T Press. Cambridge, Mass.. 1970.

Seiler, 1980. Seiler, W. and P.J. Crutzen. Climatic Change. Vol 2. 1980.

Softklone, 1987. Mirror II Version 3.6 Data Communications. (fifth edition). Softklone Distributing Corporation. Tallahassee, Fla. USA.

Spielvogel, 1978. Spielvogel, L.G. Comparisons of Energy Analysis Computer Programs. ASHRAE Journal. January, 1978.

TC, 1987. TC Limited. Thermocouple and resistance thermometry data. TC Ltd. Aberdeen. U.K.. 1987.

Tempest, 1983. Tempest, P. (Editor). British Institute of Energy Economics. Energy Economics in Britain. Graham and Trotman. London. 1982.

Thomas, 1945. Thomas, P.H. Electric Power from the Wind. Federal Power Commission. Washington, D.C.. 1945.

Thumann, 1981. Thumann, A. (Editor). Advances in Energy Utilisation Technology - Proceedings of the Fourth World Energy Engineering Congress, 1981. The Association of Energy Engineers. USA. 1981.

Thumann, 1983. Thumann, A. Handbook of Energy Audits. The Fairmont Press. Atlanta. Georgia. USA. 1983.

Tinson, 1988. Tinson, R. Address to the Parliamentary Group on Alternative Energy Strategies. House of Commons. London. 1988.

Trend, 1987. Trend Control Systems Ltd. Trend 951 Supervisor. Trend Ltd. Horsham. West Sussex. U.K.. 1987.

Trim, 1984. Trim, G. Boiler Audits help determine control system strategies. Control Engineering. June, 1984.

Tweed, 1986. Tweed, O. Industrial and Ph.D research: time for adjustment. Energy World. July, 1986.

United Nations, 1984. United Nations Statistical Office. Statistical Yearbook of the United Nations 1982. UN Publications Office. New York. 1984.

U.S. Council on Environmental Quality, 1980. The U.S. Council on Environmental Quality. The Global 2000 Report. Government Printing Office. Washington, D.C.. 1980.

Watt, 1978. The Watt Committee on Energy. The Rational Use of Energy. Report No 3. 1978.

Watt, 1979. The Watt Committee on Energy. Evaluation of Energy Use. Report No 6. 1979.

West, 1985. West, R.C. Programming the Commodore 64. Level Computer Publications. Hampstead. London. 1985.

Westinghouse, 1981(a). Westinghouse Electric Corporation - Combustion Control Division. Model 1500 General Purpose Controller Instruction Bulletin. Orville. Ohio. USA. 1981.

Westinghouse, 1981(b). Westinghouse Electric Corporation - Electronics and Control Group. Model 218 probe type oxygen analyser package. Stevenage. Herts. UK. 1981.

Williams, 1987. Williams, R.H. A low energy future for the United States. Energy Vol 12 No 10/11. 1987.

Yu, 1981. Yu, A.I. Current problems in the protection of the natural environment in the Soviet Union and in the Federal Republic of Germany. Proceedings. Soviet - West German Symposium. 1981.

Yu, 1984. Yu, A.I. Ecology and the Control of the Natural Environment. Gidrometeoizdat. Leningrad. 1984.

Yu, 1987. Yu, A.I. et al. Radioactive Contamination of the Environment in the Chernobyl Emergency Zone. Meteorologuija i Guidrologuija. Number 2. 1987.

BIBLIOGRAPHY

Aspenson, R. 3M's Tough Program Makes Dramatic Cuts in Energy Consumption. Industrial Engineering. December 1980.

Coggins, J. Techniques of Energy Management. in Industrial Energy Management: A Cost Cutting Approach. SME, Marketing Services Division. Dearborn. MI. USA. 1983.

Doebelin, E. Measurement Systems - Application and Design. McGraw Hill. Singapore. 1983.

Doering, R. Modeling an Energy Management System for a Large Central Energy Plant Complex. Industrial Engineering. December 1981.

Gochenour, D., W. Wyant and B. Windon. Energy Audit turns up many opportunities for Energy Savings in Manufacturing Plant. Industrial Engineering. December 1981.

Hirst, E. Analysis of hospital energy audits. Energy Policy. September 1982.

Lush, D. Better Energy Audits. Building Services. November 1982.

Oughton, D. Energy Management Systems. Building Services. August 1983.

Sangesland, O. Studies in Energy Retrofit at the Grumann Corporation. Heating, Piping and Air Conditioning. March 1986.

Shama, A. Energy Conservation in US Buildings- Solving the high potential/low adoption paradox from a behavioural perspective. Energy Policy. June 1983.

Turner, W and J. Mize. IE Practises Need Revaluation Due to Energy Trends. Industrial Engineering. December 1980.

World Energy Conference - 13th Congress. Proceedings Vol. 2. Energy, Economy, Environment: Main Interactions. Cannes. October 1986.

APPENDIX A

Listings of the computer programs used in the general analysis of energy use as described in chapter three are printed in this appendix.

They appear in the following order.

```
1 DIM EN(10,12),EC(10,12),CS(10),CO(10,12)
2 DIM RS(10),SS(10),TT(12),DD(12),CH(12)
10 DIM MTH$(12):NT=10
20 FOR NN =1 TO 12:READ MTH$(NN):NEXT
30 DATA "JAN","FEB","MAR","APR","MAY"
40 DATA "JUN","JUL","AUG","SEP","OCT"
50 DATA "NOV","DEC"
60 PRINT"♥" :PRINT:PRINT:PRINT:
65 PRINT" READ DATA FROM FILE (Y/N)";:INPUT ASK$
70 PRINT"♥":PRINT:PRINT:PRINT:
71 IF ASK$="N" THEN GOTO 88
72 IF ASK$<>"Y" THEN GOTO 65
73 INPUT" NAME OF INPUT FILE";IN$
74 OPEN 15,8,15:OPEN 2,8,2,IN$
75 INPUT#2,NT:INPUT#2,M1
76 FOR MM=1 TO NT
77 INPUT#2,ET$(MM):INPUT#2,CS(MM):INPUT#2,EU$(MM):INPUT#2,RS(MM):INPUT#2,SS(MM)
78 FOR PP=1 TO 12     :
79 INPUT#2,EN(MM,PP)
80 INPUT#2,EC(MM,PP):INPUT#2,CO(MM,PP):NEXT:NEXT
81 FOR N=1 TO 12
82 INPUT#2,TT(N)
83 INPUT#2,DD(N):INPUT#2,CH(N)
84 NEXT
85 CLOSE2:CLOSE15
88 PRINT"♥":PRINT:PRINT:PRINT:
89 PRINT"                              "NT
90 PRINT"C NUMBER OF ENERGY TYPES";:INPUT NT:PRINT:PRINT:
95 IF NT=0 GOTO 89
96 E$="N"
100 PRINT"                        "M1
105 PRINT"C START MONTH NO ";:INPUTM1
106 IF M1<1 GOTO 105
107 IF M1>12 GOTO 105
108 GOSUB1000:PRINT"♥":PRINT:PRINT:PRINT"                                      "E$
109 INPUT "C ENVIRONMENTAL DATA (Y/N)";E$
115 IF E$="N" GOTO 200
116 IF E$<>"Y" GOTO 109
120 PRINT"♥":PRINT:PRINT:PRINT
121 PRINT TAB(5);"MONTH";TAB(15);"O/S TEMP(F)":PRINT:PRINT
125 MT=M1-1
130 FOR N=1 TO 12:MT=MT+1
135 IF MT>12 THEN MT=MT-12
140 PRINTTAB(5);MTH$(MT);TAB(20);TT(MT)
142 PRINT"C";TAB(19);:INPUT TT(MT)
145 NEXT
146 PRINT"♥":PRINT:PRINT:PRINT
147 PRINT TAB(5);"MONTH";TAB(15);"DEG DAYS(F)":PRINT:PRINT
150 FOR N=1 TO 12:MT=MT+1
155 IF MT>12 THEN MT=MT-12
```

```
160 PRINTTAB(5);MTH$(MT);TAB(20);DD(MT)
165 PRINT"C";TAB(19);:INPUT DD(MT)
170 NEXT
200 FOR Z=1 TO NT:MT=M1-1
205 PRINT"Z"
210 PRINT"                                      "ET$(Z)
220 PRINT"C ENERGY TYPE                        ";:INPUTET$(Z)
230 PRINT"                                      "EU$(Z)
235 PRINT"C ENERGY UNITS                       ";:INPUTEU$(Z)
240 PRINT
241 MN  =0
242 IF EU$(Z) ="KWH" THEN MN  =1
243 IF EU$(Z) ="THERMS" THEN MN  =29.3
244 IF EU$(Z) ="KVA" THEN MN  =0
255 IF MN=0ANDEU$(Z)=""THENPRINT"ZROGUE UNITS":PRINT"ABOUT TO CRASH":GOTO310
265 FOR N=1 TO 12:MT=MT+1
270 IF MT>12 THEN MT=MT-12
274 EC(Z,N)= MN  *EN(Z,N)
275 PRINT TAB(8);MTH$(MT);" USAGE";TAB(14);TAB(28);EN(Z,N)
280 PRINT"C";TAB(27);:INPUT EN(Z,N)
282 EC(Z,N)=MN  *EN(Z,N)
284 PRINT TAB(8);MTH$(MT);"  COST";TAB(28);CO(Z,N)
286 PRINT"C";TAB(27);:INPUT CO(Z,N)
288 NEXT
289 RS(Z)=0:SS(Z)=0:CS(Z)=0
290 FOR N=1 TO 12
291 RS(Z)=RS(Z)+EN(Z,N):CS(Z)=CS(Z)+CO(Z,N):NEXT
292 SS(Z)=MN*RS(Z)
293 PRINT:PRINT:PRINT"      TOTAL USAGE    ";EU$(Z);TAB(26);INT(RS(Z)):PRINT
294 PRINT"       TOTAL  COST    £   ";TAB(26);INT(CS(Z)):PRINT
295 PRINT"       COST/KWH       £   ";TAB(26);(INT(10↑4*CS(Z)/RS(Z)))/10↑4
296 PRINT:AE$="N":PRINT"                        "AE$
297 PRINT"C     ANY ERRORS (Y/N)";:INPUTAE$
298 IFAE$="Y"THENGOTO205
300 DA$="Y":PRINT"Z":PRINT:PRINT:
301 PRINT"                 "DA$
302 PRINT"CMORE DATA (Y/N)";:INPUT DA$
307 IF DA$="N" THEN GOTO 310
308 IF DA$<>"Y" THEN  GOTO 302
309 NEXT
310 PRINT:PRINT"SEND DATA TO FILE (Y/N)  ";:INPUTYN$
330 IF YN$="N" THEN GOTO 360
340 IF YN$<>"Y" GOTO 310
350 GOSUB 370
360 STOP
370 REM **** SAVE RAW & CONVERTED DATA
375 INPUT"INSERT FILE NAME";F$
380 OPEN 15,8,15
390 OPEN 2,8,2,"@0:"+F$+",S,W
400 PRINT#2,NT
410 PRINT#2,M1
415 FOR Z=1 TO NT
```

```
420 PRINT#2,ET$(Z)
425 PRINT#2,CS(Z)
430 PRINT#2,EU$(Z)
435 PRINT#2,RS(Z)
436 PRINT#2,SS(Z)
440 FOR N=1 TO 12
450 PRINT#2,EN(Z,N)
451 PRINT#2,EC(Z,N)
452 PRINT#2,CO(Z,N):NEXT
455 NEXT
460 FOR N=1 TO 12
465 PRINT#2,TT(N)
470 PRINT#2,DD(N)
472 PRINT#2,CH(N)
475 NEXT
480 CLOSE2:CLOSE15:RETURN
1000 PRINT"♥":PRINT:PRINT
1002 PRINT" ENTER MONTHLY CREDIT HOURS Y/N ";:INPUT CH$
1005 IFCH$="N"THENRETURN
1025 MT=M1-1:PRINT:TCH=0
1030 FOR N=1 TO 12:MT=MT+1
1035 IF MT>12 THEN MT=MT-12
1038 PRINT"                         "CH(MT)
1040 PRINT"C                       ";MTH$(MT);:INPUTCH(MT):TCH=TCH+CH(MT):NEXT
1050 PRINT:PRINT"                     TOTAL ";TCH
1060 GETC$:IFC$=""THENGOTO1060
1100 RETURN

READY.
```

```
1 DIM EN(10,12),EC(10,12),TT(12),DD(12),CS(10),RS(10),SS(10),CO(10,12),PC(12)
10 DIM  MTH$(12),PN(10),ET$(10),EU$(10)
15 DIM  TE$(10),UE$(10),NE(10,12),KC(10)
17 DIM  CE(10,12),OC(10,12),SY(12),ZZ(10,12)
18 DIM  SUM(12),KSUM(12),PSUM(12)
20 FORNN=1TO12:READ MTH$(NN):NEXT
35 DATA "JAN","FEB","MAR","APR","MAY"
40 DATA "JUN","JUL","AUG","SEP","OCT"
50 DATA "NOV","DEC"
55 FORN=1TO12:READPC(N):NEXT
56 DATA10,6,13,1,13,10
57 DATA10,1,19,15,14,4
61 V$="KWH":IN$="INCO4"
68 PRINT"[ctrl]" :PRINT"[ctrl]                              ";IN$
73 INPUT"[ctrl]       [ctrl]NAME OF INPUT FILE";IN$
74 OPEN 15,8,15:OPEN 2,8,2,IN$
75 INPUT#2,NT:INPUT#2,M1
76 FOR MM=1 TO NT
77 INPUT#2,ET$(MM):INPUT#2,CS(MM):INPUT#2,EU$(MM):INPUT#2,RS(MM):INPUT#2,SS(MM)
78 FOR PP=1 TO 12
79 INPUT#2,EN(MM,PP)
80 INPUT#2,EC(MM,PP):INPUT#2,CO(MM,PP):NEXT:NEXT
81 FOR N=1 TO 12
82 INPUT#2,TT(N)
83 INPUT#2,DD(N)
84 NEXT
85 CLOSE2:CLOSE15
86 PRINT"[ctrl]":PRINT"[ctrl]"
87 PRINT"                          "V$
88 REM DETERMINE IF YAXIS £ OR KWH***
89 PRINT"[ctrl]     PLOT £ OR KWH VERTICALLY";:INPUT V$
90 IF V$<>"£"ANDV$<>"KWH"THENGOTO89
94 GOSUB5000:REMDETERMINE WHAT'S PLOTTED
100 GOSUB11000:REM GET MAX SUM AND EX
105 S$="Y":PRINT"[ctrl]                             ";S$
106 PRINT"  [ctrl]VIEW OUTPUT ON SCREEN (Y/N)";:INPUTS$
107 IFS$="N"THENGOTO4054
3350 REM SIMONS BASIC FOR SCREEN PLOT
3400 HIRES 0,1 :MULTI 0,1,5
3410 LINE 20, 5,20,185,1
3420 LINE 20,185,150,185,1
3435 LINE 20,186,150,186,1
3450 IC=180/DV:SU=185
3500 FOR LL=1 TO DV
3550 SU=SU-IC
3600 LINE 20,SU,22,SU,1
3610 IFLL>9THENGOTO4100
3650 CHAR 10,SU,LL+48,1,1
3700 NEXT
3750 IFV$="KWH"THENGOSUB4200
```

```
3760 IFV$="£"THENGOSUB4300
3810 FORN=1TO12:CH=15+10*N
3815 CHAR CH,192,PC(N),1,1 :NEXT
4000 C=0
4002 FOR MM=1 TO 12:SY(MM)=0:NEXT
4003 FOR PP=1 TO TN
4004 IFKC(PP)=1THENGOTO4008
4005 C=C+1
4006 IFC=4THENC=1
4008 FOR MM=1 TO 12
4009 IFCE(PP,MM)=0THENGOTO4050
4010 X=25+(MM-1)*10:X1=X+ 9
4020 Y=180*ZZ(PP,MM)/(MY*10↑EX)
4035 YP=185-INT(SY(MM)+Y):P=SY(MM)
4037 PQ=185-P
4040 BLOCK X,YP,X1,PQ,C
4045 SY(MM)=SY(MM)+Y
4050 NEXT:NEXT
4051 GETCT$:IFCT$=""THENGOTO4051
4053 NRM
4054 PRINT"▒":PRINT"▒▒▒▒▒▒▒▒▒▒      SEND OUTPUT TO PLOTTER (Y/N) ";:INPUTPL$
4055 IFPL$<>"Y"ANDPL$<>"N"THENGOTO4054
4060 IFPL$="Y"THENGOSUB7000
4070 GOTO86
4100 CHAR 5,SU,49,1,1
4110 CHAR 10,SU,LL+38,1,1
4120 GOTO3700
4200 TEXT 22,5,"▒KWH▒X▒10↑",1,1,8
4210 CHAR 78,5,XP+48,1,1:RETURN
4300 TEXT 22,5,"▒£▒X▒10↑",1,1,8
4310 CHAR 63,5,XP+48,1,1:RETURN
5000 PRINT"▒":PRINT:PRINTTAB(10);"NUMBER";TAB(20);"ENERGY TYPE":PRINT
5005 TN=NT
5010 FORN=1TONT
5020 PRINTTAB(11);N;TAB(20);ET$(N):PRINT:NEXT:PRINTTAB(11);NT+1;TAB(20);"ALL"
5030 PRINT:FORN=1TONT:KC(N)=0:NEXT
5070 PRINT" INPUT THE NUMBER OF EACH ENERGY TYPE":N=0
5080 PRINT" IN ORDER, TO BE PLOTTED.INPUT 0 TO END":JN=0
5085 PRINT" TO GROUP TYPES X NUMBER BY 10":PRINT
5090 N=N+1:INPUT" ENERGY TYPE NUMBER ";PN(N)
5094 IFPN(N)> 9THENGOSUB6100
5095 IFPN(N)=NT+1THENGOTO5110
5100 IFPN(N)<>0GOTO5090
5105 TN=N-1:JN=1:REM JN=0FLAGS PLOT ALL
5110 FORN=1TOTN:NI=PN(N):IFJN=0THENNI=N
5115 TE$(N)=ET$(NI):UE$(N)=EU$(NI)
5120 FORPP=1TO12:NE(N,PP)=EN(NI,PP):CE(N,PP)=EC(NI,PP):OC(N,PP)=CO(NI,PP)
5130 NEXT:NEXT
5140 RETURN
6100 PN(N)=PN(N)/10:KC(N)=1:RETURN
7000 REM PLOTTING ROUTINE
7005 OPEN5,5:POKE1020,128
```

```
7009 PRINT"♥":PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
7010 PRINT"    PLOTS REQUIRED:":PRINT:PRINT"    ENERGY USAGE TABLE   (1)"
7020 PRINT"    KWH-MONTH PLOT        (2)":PRINT"    £-MONTH PLOT         (3)"
7030 PRINT"    ALL OF  ABOVE         (4)":PRINT
7040 PRINT"    ENTER REQUIRED INPUT 1-4";:INPUTRE:PRINT
7045 PRINT"    HISTOGRAMS SOLID FILL(S)"
7046 PRINT"    OR EDGED ONLY         (E)";:INPUTSF$
7050 IFRE=1THENGOSUB7100
7060 IFRE=2THENGOSUB8000
7070 IFRE=3THENGOSUB9000
7080 IFRE=4THENGOSUB10000
7082 CLOSE5
7085 RETURN
7100 REM ROUTINE FOR PLOTTING ENERGY TABLE
7102 PRINT:PRINTTAB(4);"▣*PLOTTING ENERGY TABLE"
7105 PRINT#5,"IN;RO90;IP;IW;SC-1,16,-40,9;"
7110 PRINT#5,"SP2;PA0,8.5PD0,0,15,0,15,8.5,0,8.5PU;":REM OUTLINE
7115 FORN=1TO3
7120 PRINT#5,"PUPA0,";N;",PD15,";N;";PU;":NEXT:REM 3 HORIZ LINES
7130 PRINT#5,"SI.1,.2;CP2,-2;"
7132 FORN=0TO11:SS=.8*N+3.5
7140 PRINT#5,"PUPA";SS;",0PD";SS;"3;"
7150 M2=M1+N:IFM2>12THENM2=M2-12
7160 PRINT#5,"PUPA";SS;",2;CP1.5,.5;LB";MTH$(M2);"";CHR$(3):NEXT
7162 SS=SS+.7
7164 PRINT#5,"PUPA";SS;"0PD,";SS;",3;"
7166 PRINT#5,"PUPA";SS;",2;CP1.5,.5;LBTOTAL";CHR$(3):REM 13TH STR$ AND TOTAL
7167 REM LIST ENERGY TYPES TO BE PLOTTED AND LIS CLOURS USED FOR PLOTTING
7168 PRINT#5,"SP2;PUPA3.5,7.5;SI.1,.25;LBENERGY TYPE";CHR$(3)
7169 PRINT#5,"PUPA10,7.5;"
7170 PRINT#5,"LBCOLOUR";CHR$(3)
7172 P=1:FORI=1TOTN:VP=7.5-I*.7
7173 PRINT#5,"SP2;PUPA3.5,";VP;";SI.1,.2;LB";TE$(I);"";CHR$(3)
7174 IFKC(I)=1THENGOTO7178
7175 P=P+1:IFP=7THENP=1
7176 PRINT#5,"SP";P;""
7177 PRINT#5,"PT.7;FT1;"
7178 PRINT#5,"PUPA10,";VP;""
7180 PRINT#5,"RA12,";VP+.3;""
7182 NEXTI
7183 PRINT#5,"SP2;"
7184 S$=V$:V$="KWH"
7185 GOSUB11000
7186 Q$=" ENERGY  KWH X 10↑"+STR$(EK)
7190 PRINT#5,"PUPA0,1;CP2,.5;LB";Q$;"";CHR$(3)
7194 V$="£"
7195 GOSUB11000:V$=S$
7196 P$=" COST POUNDS X 10↑"+STR$(EP)
7200 PRINT#5,"PUPA0,0;CP2,.5;LB";P$;"";CHR$(3)
7210 PRINT#5,"SP2;"
7220 FORN=1TO12:SS=2.7+.8*N:REM KWH & £ FOR EACH MONTH
```

```
7224 KL=(INT(100*KSUM(N)/10↑EK))/100
7225 PRINT#5,"PUPA";SS;"1PD;CP0,.5;LB";KL;"";CHR$(3)
7229 PL=(INT(100*PSUM(N)/10↑EP))/100
7230 PRINT#5,"PUPA";SS;"0PD;CP0,.5;LB";PL;"";CHR$(3):NEXT
7235 KL=(INT(100*KGS/10↑EK))/100
7240 SS=SS+.7:PRINT#5,"PUPA";SS;"1PD;CP0,.5;LB";KL;"";CHR$(3)
7245 PL=(INT(100*PGS/10↑EP))/100
7250 PRINT#5,"PUPA";SS;"0PD;CP0,.5;LB";PL;"";CHR$(3) :REM TOTALS FOR YEAR
7260 PRINT#5,"IP;SP0;"
7300 PRINT:PRINTTAB(4);"■*TABLE PLOTTED"
7500 RETURN
8000 REM ROUINE FOR KWH V MONTHS
8002 PRINT:PRINTTAB(4);"■*PLOTTING ENERGY PLOT"
8100 V$="KWH":GOSUB11000
8500 PRINT#5,"IN;IP400,5000,10500,7500;SC-3,28,0,";DV;";RO90"
8520 PRINT#5,"PU;SP1;PA7,";DV;";SI.15,.25;CP-10,.5;"
8530 PRINT#5,"SP2:LBMONTHLY ENERGY USED";CHR$(3)
8540 PRINT#5,"PU;PA0,";DV;"PD;PA0,0,13,0;"
8550 PRINT#5,"PU;SI.1,.2;TL1,0;"
8570 FOR X=0 TO 11
8580 M2=M1+X:IF M2>12 THEN M2=M2-12
8590 PRINT#5,"PU;PA";X+1;",0;CP-2,-1;LB";MTH$(M2);"";CHR$(3)
8600 NEXT X
8610 FOR Y=0 TO DV
8620 PRINT#5,"PU;PA0,";Y;"YT;"
8630 PRINT#5,"CP-3.0,-.25;LB";Y;""CHR$(3)
8640 NEXT Y
8645 Q$=" KWH X 10↑"+STR$(EK)
8650 PRINT#5,"PU;PA0,";DV;";CP0,.5;LB";Q$;"";CHR$(3):P=1
8660 FORX=1TO12:SY(X)=0:NEXT
8670 FORI=1TOTN
8675 IFKC(I)=1THENGOTO8680
8678 P=P+1:IFP=7THENP=1
8680 PRINT#5,"SP";P;""
8685 PRINT#5,"PT.7;FT1;"
8690 FOR X=1 TO 12
8700 Y=CE(I,X)/10↑EK
8705 IFY=0THENGOTO8740
8708 IFSF$="E"THENGOTO8725
8710 PRINT#5,"PU;PA";X-0.5;Y+SY(X);""
8720 PRINT#5,"RA";X+0.5;SY(X);""
8725 PRINT#5,"PU;PA";X-0.5;Y+SY(X);""
8726 PRINT#5,"EA";X+0.5;SY(X);""
8730 SY(X)=SY(X)+Y
8740 NEXTX:NEXTI
8760 PRINT#5,"IP;SP0;"
8765 PRINT:PRINTTAB(4);"■*ENERGY PLOT PLOTTED"
8770 RETURN
9000 REM ROUINE FOR £ V MONTHS
9005 PRINT:PRINTTAB(4);"■*PLOTTING COST PLOT"
9100 V$="£":GOSUB11000
9500 PRINT#5,"IN;IP400,1000,10500,3500;SC-3,28,0,";DV;"RO90;"
```

```
9520 PRINT#5,"PU;PA7,";DV;";SI.15,.25;CP-10,.5;"
9530 PRINT#5,"SP2;LBMONTHLY ENERGY COST";CHR$(3)
9540 PRINT#5,"PU;PA0,";DV;"PD;PA0,0,13,0;"
9550 PRINT#5,"PU;SP2;SI.1,.2;TL1,0;"
9570 FOR X=0 TO 11
9580 M2=M1+X:IF M2>12 THEN M2=M2-12
9590 PRINT#5,"PU;PA";X+1;",0;CP-2,-1;LB";MTH$(M2);"";CHR$(3)
9600 NEXT X
9610 FOR Y=0 TO DV
9620 PRINT#5,"PU;PA0,";Y;"YT;"
9630 PRINT#5,"CP-3.0,-.25;LB";Y;""CHR$(3)
9640 NEXT Y
9645 Q$=" POUNDS X 10↑"+STR$(EP)
9650 PRINT#5,"PU;PA0,";DV;";CP0,.5;LB";Q$;"";CHR$(3):P=1
9660 FORX=1TO12:SY(X)=0:NEXT
9670 FORI=1TOTN
9675 IFKC(I)=1THENGOTO9680
9678 P=P+1:IFP=7THENP=1
9680 PRINT#5,"SP";P;""
9685 PRINT#5,"PT.7;FT1;"
9690 FOR X=1 TO 12
9700 Y=OC(I,X)/10↑EP
9705 IFY=0THENGOTO9740
9708 IFSF$="E"THENGOTO9725
9710 PRINT#5,"PU;PA";X-0.5;Y+SY(X);""
9720 PRINT#5,"RA";X+0.5;SY(X);""
9725 PRINT#5,"PU;PA";X-0.5;Y+SY(X);""
9726 PRINT#5,"EA";X+0.5;SY(X);""
9730 SY(X)=SY(X)+Y
9740 NEXTX:NEXTI
9760 PRINT#5,"IP;SP0;"
9765 PRINT:PRINTTAB(4);"█*COST PLOT PLOTTED"
9766 IFRE<>4THENRETURN
9767 GETC$:IFC$=""THENGOTO9767
9770 RETURN
10000 REM ROUINE FOR ALL PLOTS
10100 GOSUB7100
10110 GOSUB8000
10120 GOSUB9000
10140 RETURN
11000 REM DET MAXSUM FOR Y AXIS ROUINE
11095 IFV$="KWH"THENGOSUB12000
11100 IFV$="£"THENGOSUB12100
11104 REM GET MAX SUM FOR ALL MONTHS*****
11105 MX=0
11110 FORPP=1TO12:SUM(PP)=0
11130 FORMM=1TOTN
11140 SUM(PP)=SUM(PP)+ZZ(MM,PP):NEXT
11150 IFSUM(PP)>MXTHENMX=SUM(PP)
11155 NEXT
11162 REM DET Y END PT(MY)&EXPON(EX)*****
11170 FORN=1TO10
```

```
11180 IFMX>10↑NANDMX<10↑(N+1)THENEX=N
11190 NEXT
11200 MY=10
11210 IF MX<9.0*10↑EX THEN MY=9
11220 IF MX<6.0*10↑EX THEN MY=6
11230 IF MX<4.0*10↑EX THEN MY=4
11240 IF MX<2.0*10↑EX THEN MY=2
11250 IF MX<1.5*10↑EX THEN MY=1.5
11260 XP=EX:DV=MY
11270 IFMY<>1.5THENGOTO11285
11280 DV=15:XP=XP-1
11285 IFV$="KWH"THENGOSUB11400
11286 IFV$="£"THENGOSUB11500
11300 RETURN
11400 KGS=0:FORN=1TO12:KSUM(N)=SUM(N):KGS=KGS+SUM(N):NEXT:EK=XP:RETURN
11500 PGS=0:FORN=1TO12:PSUM(N)=SUM(N):PGS=PGS+SUM(N):NEXT:EP=XP:RETURN
12000 REM
12010 FOR PP=1 TO 12
12020 FOR MM=1 TO TN
12030 ZZ(MM,PP)=CE(MM,PP)
12040 NEXT:NEXT:RETURN
12100 REM
12110 FOR PP=1 TO 12
12120 FOR MM=1 TO TN
12130 ZZ(MM,PP)=OC(MM,PP)
12140 NEXT:NEXT:RETURN

READY.
```

```
10 DIM  PN(10),ET$(10),EU$(10),TT(12),DD(12)
15 DIM  TE$(10),UE$(10),NE(10,12),KC(10)
16 DIM  EN(10,12),EC(10,12),CS(10),RS(10),SS(10),CO(10,12),PC(12)
17 DIM  CE(10,12),OC(10,12),SY(12)
18 DIM  SUM(12),KSUM(12),PSUM(12)
19 DIM  K%(10),C%(10)
68 PRINT"□" :PRINT"■■■■■■■■"
72 IN$="INCO4":PRINT"                                    "IN$
73 INPUT"□     NAME OF INPUT FILE";IN$
74 OPEN 15,8,15:OPEN 2,8,2,IN$
75 INPUT#2,NT:INPUT#2,M1
76 FOR MM=1 TO NT
77 INPUT#2,ET$(MM):INPUT#2,CS(MM):INPUT#2,EU$(MM):INPUT#2,RS(MM):INPUT#2,SS(MM)
78 FOR PP=1 TO 12
79 INPUT#2,EN(MM,PP)
80 INPUT#2,EC(MM,PP):INPUT#2,CO(MM,PP):NEXT:NEXT
81 FOR N=1 TO 12
82 INPUT#2,TT(N)
83 INPUT#2,DD(N)
84 NEXT
85 CLOSE2:CLOSE15
86 PRINT"□":PRINT"■■■■■■■■"
100 GOSUB5000
110 GOSUB7000
115 PRINT:Y$="Y":PRINT"                                     ";Y$
120 PRINT"□      MORE PLOTS (Y/N)";:INPUTMP$
130 IFMP$="Y"THENGOTO86
140 PRINT:PRINT"     *PROGRAM ENDED"
150 STOP:END
5000 PRINT"□":PRINT:PRINTTAB(10);"NUMBER";TAB(20);"ENERGY TYPE":PRINT
5005 TN=NT
5010 FORN=1TONT
5020 PRINTTAB(11);N;TAB(20);ET$(N):PRINT:NEXT:PRINTTAB(11);NT+1;TAB(20);"ALL"
5030 PRINT:FORN=1TONT:KC(N)=0:NEXT
5070 PRINT" INPUT THE NUMBER OF EACH ENERGY TYPE":N=0
5080 PRINT" TO BE INCLUDED IN THE PIE CHART       ":JN=0
5082 PRINT" ENTER 0 TO END INPUT"
5085 PRINT" TO GROUP TYPES X NUMBER BY 10":PRINT
5086 N$="7":PRINT"                        "N$:PRINT"□□"
5090 N=N+1:INPUT" ENERGY TYPE NUMBER ";PN(N)
5094 IFPN(N)> 9THENGOSUB6100
5095 IFPN(N)=NT+1THENGOTO5110
5100 IFPN(N)<>0GOTO5090
5105 TN=N-1:JN=1:REM JN=0FLAGS PLOT ALL
5110 FORN=1TOTN:NI=PN(N):IFJN=0THENNI=N
5115 TE$(N)=ET$(NI):UE$(N)=EU$(NI)
5120 FORPP=1TO12:NE(N,PP)=EN(NI,PP):CE(N,PP)=EC(NI,PP):OC(N,PP)=CO(NI,PP)
5130 NEXT:NEXT
5140 RETURN
6100 PN(N)=PN(N)/10:KC(N)=1:RETURN
```

```
7000 REM PLOTTING ROUTINE
7005 OPEN5,5:POKE1020,128
7009 PRINT"♥":PRINT:PRINT:PRINT:PRINT:PRINT:PRINT
7010 PRINT"       PLOTS REQUIRED:":PRINT
7015 PRINT"       ANNUAL ENERGY/COST TABLE    (1)"
7020 PRINT"       ANNUAL ENERGY PLOT    (2)":PRINT"      ANNUAL COST PLOT     (3)"
7030 PRINT"       ALL OF  ABOVE         (4)":PRINT
7035 PRINT"       ENTER REQUIRED INPUT 1-4";:INPUTRE:PRINT
7040 IFMP$="Y"THENGOTO7050
7041 PRINT"♥":PRINT"▮▮▮▮▮▮▮   PLOTTER CHECK"
7042 PRINT:PRINT"       (1)  PLOTTER ON?"
7043 PRINT:PRINT"       (2)  PAPER IN?"
7044 PRINT:PRINT"       (3)  PEN NUMBERS?":PRINT
7045 PRINT"          PEN 2 FINE BLACK
7046 PRINT"          PENS 1,3,4,5,6 COLOURS
7047 PRINT"▮▮▮▮    TO PLOT-PRESS RETURN":PRINT
7048 GETC$:IFC$=""THENGOTO7048
7050 IFRE=1THENGOSUB7100
7060 IFRE=2THENGOSUB8000
7070 IFRE=3THENGOSUB9000
7080 IFRE=4THENGOSUB10000
7082 CLOSE5
7085 RETURN
7100 REM ANNUAL USAGE/COST TABLE
7105 PRINTTAB(6);"PLOTTING TABLE"
7110 PRINT#5,"IN;RO90;IP;IW;SC-2,16,-40,9;"
7120 PRINT#5,"SP2;PA0,9PD0,0,15,0,15,9,0,9PU;":REM OUTLINE
7130 PRINT#5,"PA0,1PD15,1PUPA0,6PD15,6PUPA0,7PD15,7PU;"
7140 PRINT#5,"PA7,8PD15,8PU;":REM HORZ LINES
7145 REM VERT LINES
7150 PRINT#5,"PA4,7PD4,1PUPA7,9PD7,0PUPA10,7PD10,0PUPA11,8PD11,0PUPA14,7PD14,0;"
7160 REM PRINT LABELS
7170 PRINT#5,"PUPA.5,6.1;SI.2,.25;LBENERGY TYPE";CHR$(3)
7180 PRINT#5,"PUPA4.5,6.1;LBCOLOUR";CHR$(3)
7190 PRINT#5,"PUPA8,8.1;LBANNUAL ENERGY";CHR$(3)
7200 PRINT#5,"PUPA7.5,6.1;SI.15,.2;LBKWH  %   POUNDS   % ";CHR$(3)
7210 SK=0:SP=0
7220 FORI=1TOTN:SK=SK+SS(I):SP=SP+CS(I):NEXT
7230 FORI=1TOTN:VP=6-I*.7
7240 PRINT#5,"PUPA.5,";VP;";SI.1,.2;LB";TE$(I);"";CHR$(3)
7250 SF=SS(I):GOSUB7800
7260 PRINT#5,"PUPA7.5,";VP;";LB";Q$;"";CHR$(3)
7270 K%(I)=100*SS(I)/SK:REM KWH AS %
7280 R$=STR$(INT(100*K%(I))/100)
7290 PRINT#5,"PUPA10.2,";VP;";LB";R$;"";CHR$(3)
7300 SF=CS(I):GOSUB7800
7310 PRINT#5,"PUPA11.5,";VP;";LB";Q$;"";CHR$(3)
7320 C%(I)=100*CS(I)/SP:REM COST AS %
7330 R$=STR$(INT(100*C%(I))/100)
7340 PRINT#5,"PUPA14.2,";VP;";LB";R$;"";CHR$(3)
7350 NEXT
```

```
7360 VP=VP-.7
7370 PRINT#5,"PUPA.5,";VP;";SI.1,.2;LBTOTAL";CHR$(3)
7380 SF=SK:GOSUB7800
7390 PRINT#5,"PUPA7.5,";VP;";LB";Q$;"";CHR$(3)
7400 SF=SP:GOSUB7800
7410 PRINT#5,"PUPA11.5,";VP;";LB";Q$;"";CHR$(3)
7420 P=1:REM DRAW COLOUR BARS IN TABLE
7430 FORI=1TOTN:VP=6-I*.7
7440 IFKC(I)=1THENGOTO7470
7450 P=P+1:IFP=7THENP=1
7460 PRINT#5,"SP";P;"";
7470 PRINT#5,"PT.7;FT1;"
7480 PRINT#5,"PUPA4.6,";VP;"";
7490 PRINT#5,"RA6.4,";VP+.4;"";
7495 NEXTI
7500 PRINT#5,"SP2;"
7600 PRINTTAB(5);"*TABLE PLOTTED"
7620 RETURN
7800 REM STANDARD FORM ROUTINE (SF-IN/Q$-OUT)
7810 FORN=1TO12
7820 IFSF>10↑NANDSF<10↑(N+1)THENGOTO7840
7830 NEXT
7840 EX=N:SF=(INT(100*SF/(10↑EX)))/100
7850 Q$=STR$(SF)+"X10↑"+STR$(EX)
7860 RETURN
8000 REM ANNUAL USAGE PIE CHART
8005 PRINTTAB(6);"PLOTTING ANNUAL USAGE CHART"
8010 PRINT#5,"IN;RO90;IP;IW;SC-2,16,-40,9;":SK=0
8020 FORI=1TOTN:SK=SK+SS(I):NEXT
8030 SA=0:ANG=0:P=1
8040 FORI=1TOTN
8050 SA=SA+ANG:REM SA START ANGLE
8060 ANG=INT(SS(I)*360/SK):REM ARC ANG
8070 IFKC(I)=1THENGOTO8090
8080 P=P+1:IFP=7THENP=1
8090 PRINT#5,"SP";P;"";
8100 PRINT#5,"FT3,.6,45;"
8110 PRINT#5,"PUPA7,-10;WG4.5,";SA;",";ANG;";"
8120 PRINT#5,"PUPA7,-10;EW4.5,";SA;",";ANG;";"
8130 NEXTI
8140 PRINT#5,"IP;PU;SP0;":PRINTTAB(5);"*CHART PLOTTED":RETURN
9000 REM ANNUAL COST  PIE CHART
9005 PRINTTAB(6);"PLOTTING ANNUAL COST  CHART"
9010 PRINT#5,"IN;RO90;IP;IW;SC-2,16,-40,9;":SP=0
9020 FORI=1TOTN:SP=SP+SS(I):NEXT
9030 SA=0:ANG=0:P=1
9040 FORI=1TOTN
9050 SA=SA+ANG:REM SA START ANGLE
9060 ANG=INT(CS(I)*360/SP):REM ARC ANG
9070 IFKC(I)=1THENGOTO9090
9080 P=P+1:IFP=7THENP=1
9090 PRINT#5,"SP";P;"";
```

```
9100 PRINT#5,"FT3,.6,45;"
9110 PRINT#5,"PUPA7,-30;WG4.5,";SA;",";ANG;";"
9120 PRINT#5,"PUPA7,-30;EW4.5,";SA;",";ANG;";"
9130 NEXTI
9140 PRINT#5,"IP;PU;SP0;":PRINTTAB(5);"*CHART PLOTTED":RETURN
10000 REM  PLOT ALL
10010 GOSUB7100
10020 GOSUB8000
10030 GOSUB9000
10040 RETURN

READY.
```

```
1 DIM EN(10,12),EC(10,12),TT(12),DD(12),CS(10),RS(10),SS(10),CO(10,12),PC(12)
10 DIM MTH$(12),PN(10),ET$(10),EU$(10)
15 DIM TE$(10),UE$(10),NE(10,12)
17 DIM CE(10,12),OC(10,12),SY(12),KC(10),SUM(12),DC(12),CH(12)
20 FOR NN =1 TO 12:READ MTH$(NN):NEXT
30 DATA "JAN","FEB","MAR","APR","MAY"
40 DATA "JUN","JUL","AUG","SEP","OCT"
50 DATA "NOV","DEC"
55 FORN=1TO12:READPC(N):NEXT
56 DATA10,6,13,1,13,10,10,1,19,15,14,4
68 PRINT"♥" :PRINT:PRINT:PRINT:
73 INPUT" NAME OF INPUT FILE";IN$
74 OPEN 15,8,15:OPEN 2,8,2,IN$
75 INPUT#2,NT:INPUT#2,M1
76 FOR MM=1 TO NT
77 INPUT#2,ET$(MM):INPUT#2,CS(MM):INPUT#2,EU$(MM):INPUT#2,RS(MM):INPUT#2,SS(MM)
78 FOR PP=1 TO 12
79 INPUT#2,EN(MM,PP)
80 INPUT#2,EC(MM,PP):INPUT#2,CO(MM,PP):NEXT:NEXT
81 FOR N=1 TO 12
82 INPUT#2,TT(N)
83 INPUT#2,DD(N):INPUT#2,CH(N)
84 NEXT
85 CLOSE2:CLOSE15
92 PRINT"♥":PRINT" NORMALISE W.R.T.CREDIT HOURS(Y/N) ";:INPUTCH$:CH=0
93 IFCH$="Y"THENCH=1:
94 GOSUB5000
104 REM GET MAX SUM FOR ALL MONTHS*****
105 MX=0:KS=1
110 FORPP=1TO12:SUM=0
115 IFCH=1THENKS=1/CH(PP)
130 FORMM=1TOTN
140 SUM=SUM+KS*CE(MM,PP):NEXT
150 IFSUM>MXTHENMX=SUM
155 NEXT
162 REM DET Y END PT(MO)&EXPON(EX)*****
170 FORN=1TO10
180 IFMX>10↑NANDMX<10↑(N+1)THENEX=N
190 NEXT
200 MY=10
210 IF MX<9.0*10↑EX THEN MY=9
220 IF MX<6.0*10↑EX THEN MY=6
230 IF MX<4.0*10↑EX THEN MY=4
240 IF MX<2.0*10↑EX THEN MY=2
250 IF MX<1.5*10↑EX THEN MY=1.5
3200 XP=EX:SU=185:DV=MY
3210 IFMY=1.5THENGOSUB6000
3250 IC=180/DV
3350 REM SIMONS BASIC FOR SCREEN PLOT
3400 HIRES 0,1
```

```
3410 LINE 15, 5,15,185,1
3412 LINE 15,185,295,185,1
3414 LINE 15,186,295,186,1
3420 FORKK=1TO8:HU=15+(KK-1)*40:LINE HU,185,HU,183,1:NEXT
3425 FORT=1TO3:HU=12+T*80
3430 CHAR HU-6,192,48+2*T,1,1:CHAR HU,192,48,1,1:CHAR HU+6,192,48,1,1
3435 NEXT:CHAR 12,192,48,1,1
3450 IC=180/DV
3500 FOR LL=1 TO DV
3550 SU=SU-IC
3600 LINE 15,SU,17,SU,1
3610 IFLL>9THENGOTO4100
3650 CHAR  5,SU,LL+48,1,1
3660 NEXT
3700 TEXT 235,170,"■D.DAYS ■C",1,1,8
3800 GOSUB4200
4000 FOR MM=1 TO 12:SUM(MM)=0:KS=1:IFCH=1THENKS=1/CH(MM)
4002 FORPP=1TOTN:SUM(MM)=SUM(MM)+KS*CE(PP,MM):NEXT
4005 DC(MM)=5*DD(MM)/9:REM DEGF TO DEGC
4010 XD=INT((DC(MM)*.4)+15)
4012 YM=180*SUM(MM)/(MY*10↑EX):YM=185-INT(YM)
4013 FORV=-1TO1:FORH=-1TO1:PLOT XD+H ,YM+V,1:NEXT:NEXT
4015 NEXT
4018 GOSUB6200
4020 GETCT$:IFCT$="C"THENGOTO4025
4021 IFCT$=""THENGOTO4020
4022 NRM:GOTO92
4025 COPY
4030 OPEN1,4:FORN=1TOTN
4032 PRINT#1,"          ";TE$(N):NEXT:CLOSE1:CLOSE4
4060 GETCK$:IFCK$=""THENGOTO4060
4065 NRM:  GOTO92
4100 CHAR 1,SU,49,1,1
4110 CHAR  6,SU,LL+38,1,1
4120 GOTO3660
4200 IFCH=1THENGOTO4205
4202 TEXT 45,5,"■KWH■X■10↑",1,1,8:GOTO4210
4205 TEXT 17,5,"■KWH/CH■X■10↑",1,1,8
4210 CHAR 99,5,XP+48,1,1:RETURN
5000 PRINT"■":PRINT:PRINTTAB(10);"NUMBER";TAB(20);"ENERGY TYPE":PRINT
5005 TN=NT
5010 FORN=1TONT
5020 PRINTTAB(11);N;TAB(20);ET$(N):PRINT:NEXT:PRINTTAB(11);NT+1;TAB(20);"ALL"
5030 PRINT:FORN=1TONT:KC(N)=0:NEXT
5070 PRINT" INPUT THE NUMBER OF EACH ENERGY TYPE":N=0
5080 PRINT" TO BE INCLUDED IN SUM ":JN=0
5082 PRINT" COPY--C                   REPEAT--RETURN":PRINT
5090 N=N+1:INPUT" ENERGY TYPE NUMBER ";PN(N)
5094 IFPN(N)> 9THENGOSUB6100
5095 IFPN(N)=NT+1THENGOTO5110
5100 IFPN(N)<>0GOTO5090
5105 TN=N-1:JN=1:REM JN=OFLAGS PLOT ALL
```

```
5110 FORN=1TOTN:NI=PN(N):IFJN=0THENNI=N
5115 TE$(N)=ET$(NI):UE$(N)=EU$(NI)
5120 FORPP=1TO12:NE(N,PP)=EN(NI,PP):CE(N,PP)=EC(NI,PP):OC(N,PP)=CO(NI,PP)
5130 NEXT:NEXT
5140 RETURN
6000 DV=15:XP=XP-1:RETURN
6100 PN(N)=PN(N)/10:KC(N)=1:RETURN
6200 X1=0:X2=0:Y1=0:XY=0
6210 FORN=1TO12:X1=X1+DC(N):Y1=Y1+SUM(N):X2=X2+(DC(N))↑2:XY=XY+DC(N)*SUM(N):NEXT
6215 S2=X2/12-(X1/12)↑2:SP=XY/12-(X1/12)*(Y1/12):GR=SP/S2:CO=(Y1-GR*X1)/12
6220 Y0=185-(180/(MY*10↑EX))*CO
6225 Y7=185-(180/(MY*10↑EX))*(GR*650+CO)
6226 IFY0>210ORY7<0THENGOTO6255
6240 LINE 15,Y0,275,Y7,1:RETURN
6255 Y1=185-(180/(MY*10↑EX))*(GR*100+CO)
6260 Y6=185-(180/(MY*10↑EX))*(GR*550+CO)
6265 LINE 55,Y1,235,Y6,1:RETURN

READY.
```

```
1 DIMZ$(20),UV(20),ZF$(20)
2 PG=0
10 NF=18:NE=5:NB=5:MB=1:YN$="Y":ASK$="Y"
12 DIMBD$(NB),SA(NB),SU(NB),NAC(NB),HB(NB),BA(NB),VOL(NB),VL(NB),P(NB,NF)
15 DIML(NB,NF,NE),H(NB,NF,NE),U(NB,NF,NE),A(NB,NF,NE),AU(NB,NF,NE)
16 DIMED$(NB,NF,NE),FD$(NB,NF),FO$(NB,NF),XF(NB),XE(NB,NF)
17 DIMGP(NB,NF),LG(NB,NF),HG(NB,NF)
20 PRINT"CXXXXXXXXX READ DATA FROM FILE (Y/N) ";:INPUTASK$
21 IFASK$="Y"THENGOSUB3000
22 PRINT"C":PRINT"   HARDCOPY DATA ONLY (Y/N)";:INPUTDO$:IFDO$="Y"THENGOSUB1500
23 B=1
24 F=1:BB=0:GOSUB4000
26 E=1:CC=0
28 PRINT"C":PRINT:PRINT"                                  "BD$(B):IFBB=0THENGOTO30
29 PRINT"C BUILDING DESCRIPTOR ":GOTO100
30 PRINT"C BUILDING DESCRIPTOR ";:INPUTBD$(B)
100 PRINT:PRINT" FACE NUMBER ";F:IFCC=1THENGOTO108
101 PRINT:PRINT"                                 "FD$(B,F)
102 PRINT"C FACE DESCRIPTOR (W/R/B) ";:INPUT FD$(B,F)
103 IFFD$(B,F)="DITTO"ORFD$(B,F)="D"THENGOTO400
105 IFFD$(B,F)<>"W"THENGOTO108
106 PRINT:PRINT"                              "FO$(B,F)
107 PRINT"C FACE ORIENTATION ";:INPUT FO$(B,F)
108 PRINT:PRINT" ELEM NUMBER ";E:PRINT
109 PRINT"                            "ED$(B,F,E)
110 PRINT"C ELEMENT DESCRIPTOR ";:INPUTED$(B,F,E):IFED$(B,F,E)="?"THENGOTO1800
111 IFED$(B,F,E)="NEW"THENGOTO1850
112 IFED$(B,F,E)="%"THENGOTO1900
113 IFED$(B,F,E)=""THENGOTO116
115 PRINT:GOSUB500:PRINT
116 PRINT:PRINT"                   "INT(A(B,F,E))
117 PRINT"C AREA            ";:INPUTA(B,F,E):PRINT
118 IFA(B,F,E)<>0GOTO160
119 PRINT"                  "L(B,F,E)
120 PRINT"C LENGTH          ";:INPUTL(B,F,E):PRINT
130 PRINT"                  "H(B,F,E)
140 PRINT"C HEIGHT          ";:INPUTH(B,F,E):PRINT
141 A(B,F,E)=L(B,F,E)*H(B,F,E)
145 PRINT"OOOOOC";TAB(16);INT(A(B,F,E));"XXXXX"
160 PRINT" U VALUE          "U(B,F,E):PRINT
170 PRINT"                         "YN$
180 PRINT"C MORE ELEMENTS (Y/N) ";:INPUTYN$:PRINT:PRINTB,F,E:PRINT
181 IFYN$="N"THENGOTO250
182 IFYN$="C"THENGOTO28
185 IFYN$<>"Y"THENGOTO180
200 E=E+1:IFE>NETHENGOTO1200
210 CC=1:BB=1:GOTO28
250 IFE>XE(B,F)THENXE(B,F)=E
251 CC=0:ASK$="Y"
255 PRINT:PRINT"                       "ASK$
```

```
260 PRINT"C MORE FACES    (Y/N) ";:INPUTASK$
270 IFASK$="N"THENGOTO292
275 IFASK$<>"Y"THENGOTO260
280 YN$="Y":F=F+1:IFFF>NFTHENGOTO1300
290 BB=1:GOTO26
292 IFF>XF(B)THENXF(B)=F
295 MB$="Y":PRINT:PRINT                     "MB$
296 PRINT"C MORE BUILDINGS (Y/N) ";:INPUTMB$
297 IFMB$="N"THENGOTO305
298 IFMB$<>"Y"THENGOTO296
299 YN$="Y":ASK$="Y":B=B+1:IFB>NBTHENDSTOP
300 GOTO24
305 IFB>MBTHENMB=B
306 FORB=1TOMB:SA(B)=0:SU(B)=0:FORF=1TOXF(B):FORE=1TOXE(B,F)
310 SA(B)=SA(B)+A(B,F,E)
312 IFED$(B,F,E)=""THENGOTO315
313 GOSUB500
315 SU(B)=SU(B)+A(B,F,E)*U(B,F,E):NEXT:NEXT:NEXT
318 PRINT"Ɀ":PRINT:PRINT:PRINT" DISPLAY RESULTS (Y/N) ";:INPUTDR$
319 IFDR$="Y"THENGOSUB1000
320 IFDR$<>"N"ANDDR$<>"Y"THENGOTO318
334 FL$="Y"
335 PRINT:PRINT:PRINT"                   "FL$
340 PRINT"C FILE DATA (Y/N)";:INPUTFL$
350 IFFL$="Y"THENGOSUB2000
355 IFFL$<>"N"ANDFL$<>"Y"THENGOTO340
358 HC$="N"
360 PRINT"Ɀ":PRINT:PRINT"                      "HC$
365 PRINT"C HARDCOPY DATA (Y/N)";:INPUTHC$
370 IFHC$="Y"THENGOSUB1500
375 IFHC$<>"N"ANDHC$<>"Y"THENGOTO365
380 STOP
400 REM SUB FOR REPEATING FACES WITH SAME ELEMENT
401 DIT=1:PF=F-1:FD$(B,F)=FD$(B,PF):GP(B,F)=GP(B,PF)
403 IFFD$(B,F)<>"W"THEN408
404 PRINT:PRINT"                     "FO$(B,F)
405 PRINT"C FACE ORIENTATION ";:INPUTFO$(B,F):PRINT
408 XE(B,F)=XE(B,PF)
409 IFGP(B,PF)=1THENGOTO460
410 FORE=1TOXE(B,PF):ED$(B,F,E)=ED$(B,PF,E):H(B,F,E)=H(B,PF,E)
412 U(B,F,E)=U(B,PF,E):PRINT
415 PRINT" ELEMENT NUMBER";E
416 PRINT"             "INT(A(B,F,E))
417 PRINT"C AREA       ";:INPUTA(B,F,E):PRINT
418 IFA(B,F,E)<>0GOTO445
419 PRINT"             "L(B,F,E)
420 PRINT"C LENGTH     ";:INPUTL(B,F,E):PRINT
430 PRINT"             "H(B,F,E)
440 PRINT"C HEIGHT     ";:INPUTH(B,F,E)
441 A(B,F,E)=L(B,F,E)*H(B,F,E)
445 NEXT
450 GOTO251
```

```
460 FORE=1TOXE(B,PF):ED$(B,F,E)=ED$(B,PF,E):HG(B,F)=HG(B,PF)
462 U(B,F,E)=U(B,PF,E)
463 GP(B,F)=GP(B,PF):NEXT:PRINT
469 PRINT"                    "LG(B,F)
470 PRINT"C LENGTH            ";:INPUTLG(B,F):PRINT
475 PRINT"                    "HG(B,F)
480 PRINT"C HEIGHT            ";:INPUTHG(B,F):PRINT
484 FORE=1TOXE(B,F)
485 A(B,F,E)=LG(B,F)*A(B,PF,E)/LG(B,PF)
490 NEXT
495 GOTO251
500 NN=0
505 NN=NN+1:IFNN>NUTHENGOTO1850
510 IFED$(B,F,E)<>Z$(NN)THENGOTO505
515 U(B,F,E)=UV(NN)
520 RETURN
1000 PRINT"":PRINT:PRINT
1005 FORB=1TOMB
1007 PRINT"      *****BUILDING  ";BD$(B);"******":PRINT:PRINT
1010 PRINTTAB(3);"FACE";TAB(9);"DESC(ORIE)";TAB(22);"ELEMENT";TAB(32);"DESC"
1011 PRINT
1012 PRINT"";TAB(3);"LENGTH";TAB(11);"HEIGHT";TAB(20);"AREA";TAB(27);"U"
1013 PRINT"";TAB(31);"U*AREA":PRINT
1020 FORF=1TONF
1030 FORE=1TONE
1040 IFA(B,F,E)=0ANDL(B,F,E)=0THENGOTO1100
1045 GOSUB500
1050 PRINTTAB(4);F;TAB(11)FD$(B,F);TAB(14);"(";FO$(B,F);")";TAB(24);E
1051 PRINT"C"TAB(32);ED$(B,F,E)
1055 PRINT"";TAB(3);L(B,F,E);TAB(11);H(B,F,E);TAB(18);INT(A(B,F,E))
1056 AU(B,F,E)=A(B,F,E)*U(B,F,E)
1057 PRINT"";TAB(26);U(B,F,E);TAB(31);INT(AU(B,F,E))
1060 PRINT
1100 NEXT
1110 NEXT
1112 IFSA(B)=0THENGOTO1115
1113 PRINT"  TOTALS   AREA     AREA*U    U(MEAN)":PRINT
1114 PRINTTAB(11);INT(SA(B));TAB(21);INT(SU(B));TAB(32);INT((SU(B)/SA(B))*10)/10
1115 PRINT:PRINT:NEXTB
1120 RETURN
1200 PRINT"":PRINT:PRINT" ABOUT TO CRASH":PRINT
1205 PRINT" ELEMENTS EXCEEDED":PRINT
1210 PRINT" SAVE DATA SO FAR (Y/N)";:INPUTSD$
1215 XE(B,F)=E-1
1220 IFSD$="Y"THENGOTO305
1225 STOP
1300 PRINT"":PRINT:PRINT" ABOUT TO CRASH":PRINT
1305 PRINT" FACES EXCEEDED":PRINT
1310 PRINT" SAVE DATA SO FAR (Y/N)";:INPUTSD$
1315 XF(B)=F-1
1320 IFSD$="Y"THENGOTO305
1325 STOP
```

```
1500 REM HARDCOPY ROUTINE
1505 PRINT
1510 INPUT" PRINT LIST OF DESCRIPTS (Y/N)";FF$
1540 OPEN1,4:R$=CHR$(16)
1570 FORB=1TOMB
1580 PRINT#1,"      ";CHR$(14);"BUILDING REF  ";BD$(B);CHR$(15)
1590 PRINT#1:PRINT#1,"      ";CHR$(14);"FABRIC DATA";CHR$(15):PRINT#1
1600 PRINT#1,"      FACE DESCR"R$"17ELEM"R$"22DESCR"R$"29LENGTH"CHR$(141);
1610 PRINT#1,R$"36HEIGHT"R$"43AREA"R$"51U"R$"56U*AREA"R$"64%TOT":PRINT#1
1615 FORF=1TOXF(B)
1620 FORE=1TOXE(B,F)
1625 GOSUB500:AU(B,F,E)=A(B,F,E)*U(B,F,E)
1630 PRINT#1,"     ";F;R$"10";FD$(B,F);"(";FO$(B,F);")";R$"16";E;CHR$(141);
1635 PRINT#1,R$;"22";ED$(B,F,E);R$;"28";L(B,F,E);R$;"35";H(B,F,E);CHR$(141);
1670 PRINT#1,R$;"42";INT(A(B,F,E));R$;"50";U(B,F,E);CHR$(141);
1671 PRINT#1,R$;"55";INT(AU(B,F,E));R$;"63";INT(1000*AU(B,F,E)/SU(B))/10
1675 NEXT:NEXT
1680 IFSA(B)=0THENGOTO1750
1685 PRINT#1
1690 PRINT#1,"      ";"TOTALS"R$"42";INT(SA(B));CHR$(141);
1695 PRINT#1,R$"50";INT((SU(B)/SA(B))*10)/10;R$"55";INT(SU(B))
1754 IFFF$="N"THENGOTO1780
1760 PRINT#1
1766 FORN=1TONU
1768 PRINT#1,"      ";Z$(N);R$;"17";ZF$(N)
1770 NEXT
1780 PRINT#1
1781 PRINT#1,"      ";CHR$(14)"VENTILATION DATA";CHR$(15)
1782 PRINT#1,R$"42VOL"R$"51A/C"R$"56LOAD"
1785 PRINT#1,R$"41";INT(VOL(B));R$"50";NAC(B);R$"55";INT(VL(B))
1789 PRINT#1
1790 PRINT#1,"      ";CHR$(14)"TOTAL LOAD W/DEG "CHR$(15);R$"55";INT(VL(B)+SU(B))
1791 VR=INT(10*SU(B)/VL(B))/10
1792 PRINT#1:PRINT#1,"      ";"FABRIC/VENT RATIO";R$"55";VR
1798 NEXTB
1799 CLOSE1:RETURN
1800 REM U VALUE SCREEN REMINDER
1810 PRINT"□"
1815 FORUU=1TONU
1820 PRINTTAB(10);Z$(UU);TAB(20);UV(UU)
1825 NEXT
1830 GETXX$:IFXX$=""THENGOTO1830
1840 PRINT:ED$(B,F,E)="":GOTO109
1850 REM NEW ELEMENT ROUTINE
1855 PRINT"□□□□□":NU=NU+1
1856 PRINT"                              "ED$(B,F,E)
1860 PRINT"□ ENTER NEW ELEMENT DESC  ";:INPUTZ$(NU)
1862 IFZ$(NU)=""THENGOTO1860
1863 IFZ$(NU)="OUT"THENGOTO1880
1864 ED$(B,F,E)=Z$(NU)
1865 PRINT:PRINT" ENTER U VALUE ";:INPUT UV(NU):PRINT
1870 PRINT" ENTER ELEMENT DESC IN FULL":PRINT:PRINT"     ";:INPUTZF$(NU):PRINT"□"
```

```
1872 IFPG=1THENGOTO1904
1875 PRINT:GOTO109
1880 Z$(NU)="":NU=NU-1:ED$(B,F,E)=""
1885 IFPG=1THENGOTO1904
1887 GOTO109
1900 PRINT"♥":PRINT:PRINT" PERCENTAGE GLAZING";:INPUTP:PRINT:GP(B,F)=1:GL$="SG"
1902 PRINT"                          "GL$
1903 PRINT"▯ GLASS ELEMENT DESC";:INPUTED$(B,F,E+1):PRINT
1904 PRINT"                          "ED$(B,F,E)
1905 PRINT"▯ SOLID ELEMENT DESC";:INPUTED$(B,F,E):PRINT:PG=1:GOSUB500:PG=0
1910 PRINT" TOT AREA(SOLID+GLASS)";:INPUTAT:PRINT
1915 IFAT<>0THENGOTO1935
1920 PRINT" LENGTH(SOLID+GLASS)";:INPUTLG(B,F):PRINT
1925 PRINT" HEIGHT(SOLID+GLASS)";:INPUTHG(B,F):PRINT
1930 AT=LG(B,F)*HG(B,F)
1935 A(B,F,E)=(1-P/100)*AT
1950 A(B,F,E+1)=P*AT/100
1955 GOTO115
2000 PRINT"♥":PRINT:PRINT:PRINT
2010 INPUT" INSERT FILE NAME";F$
2020 OPEN15,8,15
2030 OPEN2,8,2,"@0:"+F$+",S,W
2035 PRINT#2,MB:PRINTMB
2036 PRINT#2,NU
2037 FORT=1TONU
2038 PRINT#2,Z$(T):PRINT#2,ZF$(T)
2039 PRINT#2,UV(T):NEXT
2040 FORB=1TOMB
2042 PRINT#2,SA(B):PRINT#2,NAC(B):PRINT#2,HB(B):PRINT#2,BA(B):PRINT#2,VOL(B)
2043 PRINT#2,VL(B):PRINT#2,SU(B)
2044 PRINT#2,BD$(B):PRINTBD$(B)
2045 PRINT#2,XF(B)
2050 FORF=1TOXF(B)
2051 PRINT#2,P(B,F)
2052 PRINT#2,GP(B,F)
2053 PRINT#2,LG(B,F)
2054 PRINT#2,HG(B,F)
2055 PRINT#2,XE(B,F)
2060 PRINT#2,FD$(B,F):PRINT"****";FD$(B,F)
2065 IFFD$(B,F)<>"W"THENGOTO2080
2070 PRINT#2,FO$(B,F):PRINTFO$(B,F)
2080 FORE=1TOXE(B,F):PRINTB,F,E
2090 PRINT#2,ED$(B,F,E):PRINTED$(B,F,E)
2100 PRINT#2,L(B,F,E):PRINTL(B,F,E)
2110 PRINT#2,H(B,F,E):PRINTH(B,F,E)
2120 PRINT#2,A(B,F,E):PRINTA(B,F,E)
2150 NEXTE
2151 NEXTF
2152 NEXTB
2160 CLOSE2:CLOSE15:RETURN
3000 PRINT"♥":PRINT:PRINT:PRINT
3010 INPUT" INSERT FILE NAME";F$
```

```
3020 OPEN15,8,15
3030 OPEN2,8,2,"@0:"+F$+",S,R
3035 INPUT#2,MB:PRINTMB
3036 INPUT#2,NU
3037 FORT=1TONU
3038 INPUT#2,Z$(T):INPUT#2,ZF$(T)
3039 INPUT#2,UV(T):NEXT
3040 FORB=1TOMB
3042 INPUT#2,SA(B):INPUT#2,NAC(B):INPUT#2,HB(B):INPUT#2,BA(B):INPUT#2,VOL(B)
3043 INPUT#2,VL(B):INPUT#2,SU(B)
3044 INPUT#2,BD$(B):PRINTBD$(B)
3045 INPUT#2,XF(B)
3050 FORF=1TOXF(B)
3051 INPUT#2,P(B,F)
3052 INPUT#2,GP(B,F)
3053 INPUT#2,LG(B,F)
3054 INPUT#2,HG(B,F)
3055 INPUT#2,XE(B,F)
3060 INPUT#2,FD$(B,F):PRINT"****";FD$(B,F)
3065 IFFD$(B,F)<>"W"THENGOTO3080
3070 INPUT#2,FO$(B,F):PRINTFO$(B,F)
3080 FORE=1TOXE(B,F):PRINTB,F,E
3090 INPUT#2,ED$(B,F,E):PRINTED$(B,F,E)
3100 INPUT#2,L(B,F,E):PRINTL(B,F,E)
3110 INPUT#2,H(B,F,E):PRINTH(B,F,E)
3120 INPUT#2,A(B,F,E):PRINTA(B,F,E)
3150 NEXTE
3151 NEXTF
3152 NEXTB
3160 CLOSE2:CLOSE15:RETURN
4000 PRINT"▣":PRINT:VD$="Y":PRINT"                                         "VD$
4002 PRINT"C ENTER VENTILATION DATA (Y/N)";:INPUTVD$:PRINT
4005 IFVD$="N"THEN RETURN
4010 PRINT"                      "NAC(B)
4015 PRINT"C AIR CHANGES/HR      ";:INPUTNAC(B):PRINT
4020 PRINT"                      "HB(B)
4025 PRINT"C BUILDING HEIGHT     ";:INPUTHB(B):PRINT:IFHB(B)=0THENGOTO4100
4030 PRINT"                      "BA(B)
4035 PRINT"C BASE AREA           ";:INPUTBA(B):PRINT
4040 VOL(B)=HB(B)*BA(B)
4045 PRINT:PRINT" VOLUME OF BUILDING =";INT(VOL(B)):PRINT
4048 VL(B)=NAC(B)*VOL(B)/3
4050 PRINT" VENT LOAD PER DEG C =";INT(VL(B))
4055 GETCT$:IFCT$=""THENGOTO4055
4060 RETURN
4100 PRINT"                      "VOL(B)
4110 PRINT"C VOLUME OF BUILDING";:INPUTVOL(B):PRINT
4115 GOTO4048

READY.
```

```
1 DIMZ$(20),UV(20),ZF$(20),NF$(10)
2 PG=0
3 DIM TC(12),DC(12),HR(12)
4 DIM EN(10,12),EC(10,12),CS(10),CO(10,12),RS(10),SS(10),TT(12),DD(12)
6 DIM MTH$(12),CH(12)
10 NF=18:NE=5:NB=3:MB=1:YN$="Y":ASK$="Y"
12 DIMBD$(NB),SA(NB),SU(NB),NAC(NB),HB(NB),BA(NB),VOL(NB),VL(NB),P(NB,NF)
15 DIML(NB,NF,NE),H(NB,NF,NE),U(NB,NF,NE),A(NB,NF,NE),AU(NB,NF,NE)
16 DIMED$(NB,NF,NE),FD$(NB,NF),FO$(NB,NF),XF(NB),XE(NB,NF)
17 DIMGP(NB,NF),LG(NB,NF),HG(NB,NF)
20 FORN=1TO12:READHR(N):HR(N)=24*HR(N):NEXT:REM HOURS IN MONTHS
25 DATA 31,28,31,30,31,30,31,31,30,31,30,31
100 PRINT""
101 PRINT" BUILDING SURVEY FILES":PRINT
102 PRINT" DO YOU WISH TO ":PRINT
103 PRINT"          ENTER NEW DATA (N)"
104 PRINT"          REVIEW DATA    (R)";:INPUTQ1$
110 IFQ1$="N"THENGOSUB1000
115 IFQ1$<>"N"ANDQ1$<>"R"THENGOTO102
116 IFQ1$="R"THENGOSUB1500
118 GOSUB4000
119 IFQ1$="R"THENGOTO170
120 PRINT"FILE DATA (Y/N)";:INPUTFD$
130 IFFD$="Y"THENGOSUB2000
140 IFFD$="N"THENGOTO200
160 GETC$:IFC$=""THENGOTO160
170 CC=-1
200 PRINT"ENTER INSIDE TEMP";:INPUTT1:CC=CC+1
210 IFCC>0THENGOTO275
245 PRINT:PRINT"  NOW ENTER TEMP & DEGDAY DATA"
250 F$="INC04":PRINT:PRINT"                           "F$
260 PRINT"C  ENTER FILE NAME  ";:INPUTF$
265 GOSUB2380
275 FORN=1TO12:TC(N)=(TT(N)-32)*5/9:DC(N)=DD(N)*5/9:NEXT:REM DEG F TO DEG C
300 NT=2:ZE=0:FORN=1TO12
310 EN(1,N)=TU*(T1-TC(N))*HR(N)/1000:REM EN(1,N)=FABRICLOAD,HR(N)=HOURS IN MONTH
315 EN(2,N)=TL*(T1-TC(N))*HR(N)/1000:REM VENT LOAD
320 FORZ=1TONT:EC(Z,N)=EN(Z,N):CO(Z,N)=0
326 ZE=ZE+EN(Z,N):NEXT:NEXT
327 PRINT"TOTAL ENERGY LOSS (KWHR)= ";INT(ZE)
328 PRINT"REPEAT(R) OR RET TO CONTINUE";
329 INPUTC$:IFC$="R"THENGOTO200
330 ET$(1)="FAB/LOAD":ET$(2)="VENT/LOAD":EU$(1)="KWH":EU$(2)="KWH"
352 CS(1)=-1:CS(2)=T1:REM WAY OF OUTPUTING T1 WITHOUT MAJOR FILE CHANGES
355 REM RS(Z)=ANNUAL LOAD FOR EN TYPE Z
360 PRINT"   SAVE FAB & VENT DATA (Y/N)";:INPUTFV$
361 IFFV$="N"THENGOTO900
362 PRINT:PRINT:PRINT"    FILE NAME IS TOTLOAD"
363 F$="TOTLOAD"
365 IFFV$="Y"THENGOSUB2180
```

```
366 IFFV$<>"N"ANDFV$<>"Y"THENGOTO360
850 GETC$:IFC$=""THENGOTO850
900 STOP
1000 REM
1100 PRINT"[illegible]ENTER NO.OF BUILDINGS";:INPUTBB
1110 PRINT:PRINT" LIST BUILDING FILES":PRINT
1120 FORN=1TOBB:PRINT" ENTER FILE NAME ";:INPUTNF$(N)
1130 NEXTN
1140 PRINT:PRINT" END OF LIST OF FILES"
1145 PRINT"[illegible]HIT RETURN"
1150 GETC$:IFC$=""THEN1150
1170 FORN=1TOBB:PRINT"[illegible]":GOSUB3000
1180 FORB=1TOMB
1190 TA=TA+SA(B):TU=TU+SU(B)
1210 TV=TV+VOL(B):TL=TL+VL(B)
1220 GT=GT+SU(B)+VL(B)
1300 NEXTN
1310 TMU=INT(TU*10/TA)/10
1360 RETURN
1500 REM
1520 OPEN15,8,15:F$="ALLSUR"
1530 OPEN2,8,2,"@0:"+F$+",S,R
1531 PRINT"[illegible]   FILE NAME IS ";F$
1535 INPUT#2,BB
1540 FORN=1TOBB:INPUT#2,NF$(N):NEXT
1550 INPUT#2,TA
1555 INPUT#2,TU
1560 INPUT#2,TV
1565 INPUT#2,TL
1570 INPUT#2,GT
1575 INPUT#2,SB
1580 TMU=INT(TU*10/TA)/10
1600 CLOSE2:CLOSE15:RETURN
2000 REM
2020 OPEN15,8,15:F$="ALLSUR"
2030 OPEN2,8,2,"@0:"+F$+",S,W
2031 PRINT"[illegible]   FILE NAME IS ";F$
2035 PRINT#2,BB
2040 FORN=1TOBB:PRINT#2,NF$(N):NEXT
2050 PRINT#2,TA
2055 PRINT#2,TU
2060 PRINT#2,TV
2065 PRINT#2,TL
2070 PRINT#2,GT
2075 PRINT#2,SB
2080 CLOSE2:CLOSE15:RETURN
2180 OPEN 15,8,15
2190 OPEN 2,8,2,"@0:"+F$+",S,W
2200 PRINT#2,NT
2210 PRINT#2,M1
2215 FOR Z=1 TO NT
2220 PRINT#2,ET$(Z)
```

```
2225 PRINT#2,CS(Z):REMCS(2)=INT.TEMP
2230 PRINT#2,EU$(Z)
2235 PRINT#2,RS(Z)
2236 PRINT#2,SS(Z)
2240 FOR N=1 TO 12
2250 PRINT#2,EN(Z,N)
2251 PRINT#2,EC(Z,N)
2252 PRINT#2,CO(Z,N):NEXT
2255 NEXT
2260 FOR N=1 TO 12
2265 PRINT#2,TT(N)
2270 PRINT#2,DD(N)
2272 PRINT#2,CH(N)
2275 NEXT
2280 CLOSE2:CLOSE15:RETURN
2380 OPEN 15,8,15
2390 OPEN 2,8,2,"@O:"+F$+",S,R
2400 INPUT#2,NT
2410 INPUT#2,M1
2415 FOR Z=1 TO NT
2420 INPUT#2,ET$(Z)
2425 INPUT#2,CS(Z)
2430 INPUT#2,EU$(Z)
2435 INPUT#2,RS(Z)
2436 INPUT#2,SS(Z)
2440 FOR N=1 TO 12
2450 INPUT#2,EN(Z,N)
2451 INPUT#2,EC(Z,N)
2452 INPUT#2,CO(Z,N):NEXT
2455 NEXT
2460 FOR N=1 TO 12
2465 INPUT#2,TT(N)
2470 INPUT#2,DD(N)
2472 INPUT#2,CH(N)
2475 NEXT
2480 CLOSE2:CLOSE15:RETURN
3000 REM
3020 OPEN15,8,15
3030 OPEN2,8,2,"@O:"+NF$(N)+",S,R
3035 INPUT#2,MB:PRINTMB
3036 INPUT#2,NU
3037 FORT=1TONU
3038 INPUT#2,Z$(T):INPUT#2,ZF$(T)
3039 INPUT#2,UV(T):NEXT
3040 FORB=1TOMB
3042 INPUT#2,SA(B):INPUT#2,NAC(B):INPUT#2,HB(B):INPUT#2,BA(B):INPUT#2,VOL(B)
3043 INPUT#2,VL(B):INPUT#2,SU(B)
3044 INPUT#2,BD$(B):PRINTBD$(B)
3045 INPUT#2,XF(B)
3050 FORF=1TOXF(B)
3051 INPUT#2,P(B,F)
3052 INPUT#2,GP(B,F)
```

```
3053 INPUT#2,LG(B,F)
3054 INPUT#2,HG(B,F)
3055 INPUT#2,XE(B,F)
3060 INPUT#2,FD$(B,F):PRINT"****";FD$(B,F)
3065 IFFD$(B,F)<>"W"THENGOTO3080
3070 INPUT#2,FO$(B,F):PRINTFO$(B,F)
3080 FORE=1TOXE(B,F):PRINTB,F,E
3090 INPUT#2,ED$(B,F,E):PRINTED$(B,F,E)
3100 INPUT#2,L(B,F,E):PRINTL(B,F,E)
3110 INPUT#2,H(B,F,E):PRINTH(B,F,E)
3120 INPUT#2,A(B,F,E):PRINTA(B,F,E)
3125 IFFD$(B,F)="B"THENSB=SB+A(B,F,E)
3150 NEXTE
3151 NEXTF
3152 NEXTB
3160 CLOSE2:CLOSE15:RETURN
4000 PRINT"[illegible]     DATA FOR WHOLE SITE":PRINT:PRINT:PRINT
4010 PRINT"      FABRIC AREA        ";INT(TA)
4020 PRINT"      U*AREA LOAD        ";INT(TU)
4030 PRINT"      SITE U VALUE       ";TMU
4035 PRINT"      BASE AREA          ";INT(SB)
4040 PRINT"      VOLUME BUILDINGS   ";INT(TV)
4050 PRINT"      VENT   LOAD        ";INT(TL)
4055 PRINT"      FABRIC/VENT RATIO  ";INT(10*TU/TL)/10:PRINT"[illegible]"
4060 PRINT"      TOTAL  LOAD        ";INT(GT):PRINT:PRINT
4061 PRINT"      COMPONENT FILES":PRINT
4062 NL=INT(BB/4)+1:BX=BB/4-INT(BB/4)
4063 IFBX=0THENNL=NL-1
4066 FORN=1TONL:M=4*N-3:PRINT"      ";NF$(M);TAB(12);NF$(M+1);TAB(22);NF$(M+2)
4067 PRINT"C";TAB(32);NF$(M+3)
4070 NEXT
4075 GETC$:IFC$=""THEN4075
4080 RETURN

READY.
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```
10 DIM  PN(10),ET$(10),EU$(10),TT(12),DD(12),TC(12),DC(12),HR(12),CH(12)
15 DIM  TE$(10),UE$(10),NE(10,12),KC(10)
16 DIM  EN(10,12),EC(10,12),CS(10),RS(10),SS(10),CO(10,12),PC(12)
17 DIM  CE(10,12),OC(10,12),SY(12)
18 DIM  SUM(12),KSUM(12),PSUM(12)
19 DIM  K%(10),C%(10),CF(10),DF(10)
20 DIM  R1(10,6),R2(10,6),RB(4),SH(4)
30 DIM  BSH(10,7,4),X(10,7),BC$(10,2,7),BR$(5),HS$(4),LS$(8),ML$(7,4)
35 DIM  VT(10),WS(10),WG(10),RQ(10)
37 DIM  UQ(10),BA(10),RG(10)
40 FORN=1TO12:READHR(N):HR(N)=24*HR(N):NEXT:REM HOURS IN MONTHS
42 DATA 31,28,31,30,31,30,31,31,30,31,30,31
68 PRINT"" :PRINT""
72 IN$="INCO4":PRINT"                                   "IN$
73 INPUT"C      NAME OF INPUT FILE";IN$
74 OPEN 15,8,15:OPEN 2,8,2,IN$
75 INPUT#2,NT:INPUT#2,M1
76 FOR MM=1 TO NT
77 INPUT#2,ET$(MM):INPUT#2,CS(MM):INPUT#2,EU$(MM):INPUT#2,RS(MM):INPUT#2,SS(MM)
78 FOR PP=1 TO 12
79 INPUT#2,EN(MM,PP)
80 INPUT#2,EC(MM,PP):INPUT#2,CO(MM,PP):NEXT:NEXT
81 FOR N=1 TO 12
82 INPUT#2,TT(N)
83 INPUT#2,DD(N):INPUT#2,CH(N)
84 NEXT
85 CLOSE2:CLOSE15
86 PRINT"":PRINT"":A$="Y"
89 PRINT"                                        "A$
95 PRINT"C READ CONV/DIST EFFICIENCIES (Y/N)";:INPUTA$:PRINT:B$="N"
100 IFA$="Y"THENGOSUB1000
110 PRINT"                                   "B$
120 PRINT"C DISPLAY EFFICIENCIES (Y/N)";:INPUTB$
130 IFB$="N"THENGOTO240
140 PRINT:FORN=1TONT:PRINT
150 PRINT"                      "ET$(N)
160 PRINT"C  ENERGY TYPE ";:INPUTET$(N)
170 PRINT:PRINT"                      "CF(N)
180 PRINT"C  CONVERSION EFF";:INPUTCF(N)
190 PRINT:PRINT"                      "DF(N)
200 PRINT"C  DISTRIBUT  EFF";:INPUTDF(N)
210 NEXTN
220 PRINT:PRINT"  FILE EFFICIENCIES (Y/N)";:INPUTC$
230 IFC$="Y"THENGOSUB1200
240 REM EVALUATE ENERGY FIGURES
250 SK=0:SP=0:FORN=1TONT:SK=SK+SS(N):SP=SP+CS(N):NEXT
260 PRINTSK,SP
270 FORN=1TONT:F1=1-CF(N)/100:F2=1-DF(N)/100
280 R1(N,3)=F1*SS(N)
290 R1(N,4)=100*R1(N,3)/SK
```

```
300 R1(N,5)=F1*CS(N)
310 R1(N,6)=100*R1(N,5)/SP
320 IFDF(N)=100THENGOTO370
330 R2(N,3)=(CF(N)/100)*F2*SS(N)
340 R2(N,4)=100*R2(N,3)/SK
350 R2(N,5)=(CF(N)/100)*F2*CS(N)
360 R2(N,6)=100*R2(N,5)/SP
370 RE=RE+(CF(N)/100)*(DF(N)/100)*SS(N)
375 RM=RM+(CF(N)/100)*(DF(N)/100)*CS(N)
376 UC=RM/RE
380 REM     PRINTN,RE,RM
385 NEXT
390 FORN=1TONT:FORB=3TO6
400 REM   PRINTET$(N),N;B,R1(N,B):NEXT
405 FORB=3TO6
410 REM   PRINTN,B,R2(N,B):NEXT
430 NEXT
440 REM PRINT:PRINT"ENERGY LEFT= ";RE
445 REM PRINT:PRINT"MONEY  LEFT= ";RM
446 REM PRINT:PRINT"UNIT COST  =  ";UC
447 REM GETC$:IFC$=""THENGOTO447
450 GOSUB6000
460 REM EVALUATE RESIDUAL RL
465 RL=RE-ZE:RB(1)=RL
470 RB(2)=(RL/SK)*100:RB(3)=RL*UC:RB(4)=RB(3)*100/SP
472 GOTO495
475 PRINT:PRINT"RESIDUAL FIGURES BOXES 1-4":PRINT
480 FORN=1TO4:PRINTRB(N):NEXT
485 PRINT:PRINT"TOTAL SP.HEATING BOXES 1-4":PRINT
490 REM TOTAL SPACE HEATING BOXES
495 SH(1)=ZE:SH(2)=ZE*100/SK:SH(3)=ZE*UC:SH(4)=SH(3)*100/SP:GOTO500
496 FORN=1TO4:PRINTSH(N):NEXT
498 GETC$:IFC$=""THENGOTO498
499 PRINT"[illegible]DON'T TOUCH"
500 REM VENT & FAB FIGS FOR BUILDINGS
510 FORN=1TOBB
511 X(N,1)=VT(N)
512 X(N,2)=UQ(N)
513 X(N,3)=WS(N)
514 X(N,4)=WG(N)
515 X(N,5)=RQ(N)
516 X(N,6)=RG(N)
517 X(N,7)=BA(N)
518 NEXT
520 FORN=1TOBB:FORM=1TO7:X(N,M)=X(N,M)*ZE/GT:NEXT:NEXT
522 GOTO635
525 FORN=1TOBB:FORM=1TO7
530 BSH(N,M,1)=X(N,M):BSH(N,M,2)=BSH(N,M,1)*100/SK:BSH(N,M,3)=BSH(N,M,1)*UC
535 BSH(N,M,4)=BSH(N,M,3)*100/SP
540 NEXT:ZZ=ZZ+X(N,1)+X(N,2):NEXT
550 FORN=1TOBB:FORM=1TO7:FORP=1TO4
555 BSH(N,M,P)=INT(100*BSH(N,M,P))/100
```

```
560 NEXT:NEXT:NEXT
570 FORN=1TOBB:PRINT"":PRINT" BUILDING REF ";NF$(N):PRINT:PRINT
575 PRINT"     KWH       %KWH        £          %£":PRINT""
580 FORM=1TO7
585 PRINTBSH(N,M,1);TAB(13);BSH(N,M,2);TAB(20);BSH(N,M,3);TAB(33);BSH(N,M,4)
590 NEXT
600 GETC$:IFC$=""THENGOTO600
610 NEXT
620 PRINT:PRINT"SUM OF ENERGIES=";ZZ
625 PRINT:PRINT"SHOULD BE      =";ZE
630 GETC$:IFC$=""THENGOTO630
635 AU$="Y":PRINT"                                      ";AU$
640 PRINT"          PLOT AUDIT (Y/N)";:INPUTAU$
650 IFAU$="Y"THENGOSUB7000:REM PLOTTING ROUTINE
900 STOP
1000 OPEN15,8,15:F$="CONV/DIST EFF"
1010 OPEN2,8,2,"@0:"+F$+",S,R
1015 INPUT#2,NT
1020 FORN=1TONT
1030 INPUT#2,ET$(N)
1040 INPUT#2,CF(N)
1050 INPUT#2,DF(N)
1060 NEXTN
1070 CLOSE2:CLOSE15:RETURN
1200 OPEN15,8,15:F$="CONV/DIST EFF"
1210 OPEN2,8,2,"@0:"+F$+",S,W
1215 PRINT#2,NT
1220 FORN=1TONT
1230 PRINT#2,ET$(N)
1240 PRINT#2,CF(N)
1250 PRINT#2,DF(N)
1260 NEXTN
1270 CLOSE2:CLOSE15:RETURN
6000 REM CALC TOTAL ENERGY LOSS IN BUILDINGS
6100 GOSUB6500
6200 PRINT"ENTER INSIDE TEMP";:INPUTT1
6275 FORN=1TO12:TC(N)=(TT(N)-32)*5/9:DC(N)=DD(N)*5/9:NEXT:REM DEG F TO DEG C
6290 FORN=1TO12:EN(1,N)=0:EN(2,N)=0:NEXT
6300 ZE=0:FORN=1TO12
6310 EN(1,N)=TU*(T1-TC(N))*HR(N)/1000:REM FABRIC LOAD HR(N)=HOURS IN MONTHS
6315 EN(2,N)=TL*(T1-TC(N))*HR(N)/1000:REM VENT LOAD
6316 REM PRINTINT(1000*TC(N))/1000;TAB(10);INT(EN(1,N));TAB(25);INT(EN(2,N))
6320 FORZ=1TO2:EC(Z,N)=EN(Z,N):CO(Z,N)=0
6326 ZE=ZE+EN(Z,N):NEXT:NEXT
6327 REM PRINT"TOTAL ENERGY LOSS (KWHR)= ";INT(ZE)
6330 REM GETC$:IFC$=""THENGOTO6330
6340 RETURN
6500 REM
6520 OPEN15,8,15:F$="ALLSUR"
6530 OPEN2,8,2,"@0:"+F$+",S,R
6531 PRINT"INPUT DATA FOR TOTAL SITE"
6534 PRINT"FILE NAME IS ";F$
```

```
6535 INPUT#2,BB
6540 FORN=1TOBB
6541 INPUT#2,NF$(N)
6542 INPUT#2,VT(N)
6543 INPUT#2,UQ(N)
6544 INPUT#2,WS(N)
6545 INPUT#2,WG(N)
6546 INPUT#2,RQ(N)
6547 INPUT#2,RG(N)
6548 INPUT#2,BA(N)
6549 NEXT
6550 INPUT#2,TA
6555 INPUT#2,TU
6560 INPUT#2,TV
6565 INPUT#2,TL
6570 INPUT#2,GT
6575 INPUT#2,SB
6580 TMU=INT(TU*10/TA)/10
6590 CLOSE2:CLOSE15:RETURN
7000 REM PLOTTING ROUTINE
7010 OPEN5,5:POKE1020,128
7015 PRINT"■":PRINT"■■■■■    PLOTTER CHECK"
7020 PRINT:PRINT"          (1)  PLOTTER ON":PRINT
7025 PRINT:PRINT"          (2)  PAPER IN":PRINT
7030 PRINT:PRINT"          (3)  PEN NUMBERS":PRINT:PRINT
7035 PRINT"          PEN 2 FINE BLACK"
7040 PRINT"          PENS 1,3,4,5,6,COLOURS"
7045 PRINT"■■■■    TO PLOT-PRESS RETURN":PRINT
7050 GETP$:IFP$=""THENGOTO7050:PRINT
7055 PRINTTAB(2);"■*PLOTTING AUDIT":NP=1:TL=86
7100 PRINT#5,"IN;RO90;IP;IW;SC-5,72,0,108;SP2;":Y=111
7105 EBT=0:GOSUB8000:REM TOP OF PAGE TITLES
7110 FORN=1TONT:VR=2:IFDF(N)=100THENVR=1
7111 IFN=1ANDVR=1THENTL=93
7112 Y=Y-11
7115 GOSUB8500
7120 FORRV=1TOVR:X=3+(RV-1)*15:Y=Y-(RV-1)*7
7130 FORBN=RVTO6:DX=11:IFBN=4ORBN=6THENDX=6
7131 IFBN=1THENDX=12
7135 PRINT#5,"SI.13,.19;"
7140 PRINT#5,"PUPA";X,Y;"PD";X+DX,Y,X+DX,Y-4,X,Y-4,X,Y;"PU;":REM BOX
7150 IFBN=2ANDRV=1THENPRINT#5,"PA";X-3,Y-2;"PD";X,Y-2;"PU;":REM LINE BOX 1-
7160 IFBN=2THENPRINT#5,"PUPA23.5,";Y-4;"PD23.5,";Y-7;"PU;"
7162 XL=X+2.0:YL=Y-2.5:IFBN=2THENGOSUB8300
7163 IFBN=4ORBN=6THENXL=XL-1
7165 PRINT#5,"PUPA";XL,YL;";LB";BC$(N,RV,BN);"";CHR$(3)
7170 X=X+DX+3:NEXTBN
7190 NEXTRV
7200 PRINT#5,"PUPA23.5,";Y-7;"PD2,";Y-7;"PU;"
7210 IFY<31THENGOSUB8200
7215 PRINTTAB(6);N,ET$(N),Y
7220 NEXTN
```

```
7230 IFY<>100THENY=Y-11:REM TRUE ONLY FOR PAGE CHANGE
7240 REM RESIDUAL BOX
7250 X=18:GOSUB8800:PRINT#5,"SI.13,.19;"
7260 FORBN=1TO5:DX=11:IFBN=3ORBN=5THENDX=6
7270 PRINT#5,"PUPA";X,Y;"PD";X+DX,Y,X+DX,Y-4,X,Y-4,X,Y;"PU;"
7280 XL=X+2:YL=Y-2:IFBN=3ORBN=5THENXL=XL-1.5
7290 PRINT#5,"PUPA";XL,YL;";LB";BR$(BN);"";CHR$(3)
7300 X=X+DX+3
7310 NEXTBN
7320 PRINT#5,"PUPA18,";Y-2;"PD2,";Y-2;"PU;"
7325 PRINT:PRINTTAB(6);"RESIDUAL BOX DRAWN"
7330 REM BOX TOT ENERGY TO BUILDINGS
7340 IFY<25THENGOSUB8200
7350 Y=Y-10
7360 PRINT#5,"PUPA0,";Y;"PD29,";Y;",29,";Y-10;",0,";Y-10;",0,";Y;"PU;"
7370 EBT=Y
7375 PRINT:PRINTTAB(6);"ENERGY   BOX DRAWN"
7380 PRINT#5,"SI.2,.25;PUPA7,";Y-3;";LBTOTAL ENERGY";CHR$(3)
7390 PRINT#5,"PUPA12.5,";Y-5;";LBTO";CHR$(3)
7400 PRINT#5,"PUPA9,";Y-7;";LBBUILDINGS";CHR$(3)
7410 HS$(1)=STR$(INT(SH(1)/1000))
7420 HS$(2)=STR$(INT(SH(2)*100)/100)
7430 HS$(3)=STR$(INT(SH(3)))
7440 HS$(4)=STR$(INT(SH(4)*100)/100)
7450 PRINT#5,"SI.13,.19;PUPA32,";Y-5;";LB";HS$(1);"";CHR$(3)
7460 PRINT#5,"PUPA45,";Y-5;";LB";HS$(2);"";CHR$(3)
7465 PRINT#5,"PUPA53,";Y-5;";LB";HS$(3);"";CHR$(3)
7470 PRINT#5,"PUPA66,";Y-5;";LB";HS$(4);"";CHR$(3)
7480 REM BUILDING BOXES
7490 IFY<42THENGOSUB6000
7500 Y=Y-15
7505 GOSUB9100:REM DEFINE ROW TITLES
7510 FORN=1TOBB:YT=Y
7511 PRINT#5,"PUPA5,";Y;"PD29,";Y;",29,";Y-27;",5,";Y-27;",5,";Y;"PU;"
7512 PRINT:PRINT"  [?]BUILDING ";N;"  ";NF$(N)
7513 PRINT#5,"PUPA5,";Y-2.5;"PD2,";Y-2.5;"PU;"
7515 GOSUB8900:REM PRINT TITLE
7520 FORL=1TO8:Y=Y-3
7530 IFL=1THENY=Y-2
7540 IFL=3THENY=Y+2
7545 IFL<>2THENGOSUB9000:PRINT TITLES
7550 PRINT#5,"PUPA5,";Y;"PD29,";Y;"
7555 NEXTL
7560 Y=YT-1
7570 FORM=1TO7:Y=Y-3:X=31:IFM<3THENY=Y-1
7575 GOSUB9200
7576 PRINT:IFM>1THENPRINT"C[?]          ";LS$(M+1)
7577 IFM=1THENPRINT"C[?]          ";LS$(1)
7578 FORBN=1TO4:PRINTBN,ML$(M,BN):NEXT
7579 REM GETC$:IFC$=""THENGOTO7579
7580 FORBN=1TO4:DX=11:IFBN=2ORBN=4THENDX=6
7585 XL=X+2:IFBN=2ORBN=4THENXL=X+.5
```

```
7590 IFM=1ORM=2THENPRINT#5,"PUPA";X,Y;"PD";X+DX,Y,X+DX,Y-3,X,Y-3,X,Y;";PU;"
7595 PRINT#5,"SI.13,.19;PUPA";XL,Y-2;";LB";ML$(M,BN);"";CHR$(3)
7605 X=X+DX+3
7610 NEXTBN:NEXTM
7620 Y=YT-29
7630 IFY<27ANDN<BBTHENGOSUB8200
7670 NEXTN
7680 PRINT#5,"PUPA2,";TL;"PD2,";YT-2.5;"PU;SP0;"
7690 PRINT:PRINT:PRINTTAB(2);"*PLOTTING ENDED":PRINT""
7700 CLOSE5
7710 RETURN
8000 REM TOP OF PAGE TITLES************
8005 PRINT#5,"SI.15,.3;"
8010 PRINT#5,"SP2;PUPA32.5,106;LBENERGY LOSS";CHR$(3)
8020 PRINT#5,"PUPA47,106;LB% TOT";CHR$(3)
8030 PRINT#5,"PUPA58,106;LBCOST";CHR$(3)
8040 PRINT#5,"PUPA69.5,106;LB% TOT";CHR$(3)
8050 PRINT#5,"SI.15,.20;"
8060 PRINT#5,"PUPA35,104;LBMW-HR";CHR$(3)
8070 PRINT#5,"PUPA58,104;LBPOUNDS";CHR$(3)
8080 PRINT#5,"SI.2,.15;"
8090 RETURN
8200 REM NEW PAGE ROUTINE
8210 LS=EBT
8220 IFLS=0THENPRINT#5,"PUPA2,";TL;"PD2,0;"
8225 IFLS<>0THENPRINT#5,"PUPA2,";TL;"PD2,";LS;"PUPA2,";LS-10;"PD2,0;"
8226 PRINT#5,"PUPA1.5,3PD2,1,2.5,3PU;SP0;"
8230 PRINT"END OF PAGE ";NP:PRINT
8240 PRINT"INSERT NEW PAPER & PRESS RETURN":NP=NP+1
8245 GETC$:IFC$=""THENGOTO8245
8250 PRINT"PLOTTING PAGE ";NP
8260 Y=100:TL=100:EBT=0:GOSUB8000
8270 RETURN
8300 REM PRINT "CONV EFF"/"DIST EFF"
8305 YL=YL+.5:PRINT#5,"SI.13,.19;"
8310 IFRV=1THENPRINT#5,"PUPA";XL,YL;";LBCONV EFF";CHR$(3)
8320 IFRV=2THENPRINT#5,"PUPA";XL,YL;";LBDIST EFF";CHR$(3)
8330 YL=YL-1.5:XL=XL+2:RETURN
8500 REM BOX CONTENTS-ENERGY IN
8600 BC$(N,1,1)=ET$(N)
8610 BC$(N,1,2)=STR$(INT(CF(N)))
8620 BC$(N,1,3)=STR$(INT(R1(N,3)/1000))
8630 BC$(N,1,4)=STR$(INT(R1(N,4)*100)/100)
8640 BC$(N,1,5)=STR$(INT(R1(N,5)))
8650 BC$(N,1,6)=STR$(INT(R1(N,6)*100)/100)
8660 IFVR=1THENRETURN
8670 BC$(N,2,2)=STR$(INT(DF(N)))
8680 BC$(N,2,3)=STR$(INT(R2(N,3)/1000))
8690 BC$(N,2,4)=STR$(INT(R2(N,4)*100)/100)
8700 BC$(N,2,5)=STR$(INT(R2(N,5)))
8710 BC$(N,2,6)=STR$(INT(R2(N,6)*100)/100)
8720 RETURN
```

```
8800 REM BOX CONTENTS-RESIDUAL
8805 BR$(1)="RESIDUAL"
8810 BR$(2)=STR$(INT(RB(1)/1000))
8820 BR$(3)=STR$(INT(RB(2)*100)/100)
8830 BR$(4)=STR$(INT(RB(3)))
8840 BR$(5)=STR$(INT(RB(4)*100)/100)
8850 RETURN
8900 REM BUILDING TITLE
8910 IFLEN(NF$(N))=5THENNM$=LEFT$(NF$(N),2)+" BLOCK"
8920 IFLEN(NF$(N))=4THENNM$=LEFT$(NF$(N),1)+" BLOCK"
8925 PRINTTAB(6)NM$
8930 PRINT#5,"SI.2,.25;PUPA9,";Y-3;";LB";NM$;"";CHR$(3)
8940 PRINT#5,"SI.2,.15;":RETURN
9000 REM PRINT ROW TITLES
9010 PRINT#5,"SI.20,.15;PUPA7,";Y-2;";LB";LS$(L);"";CHR$(3)
9020 RETURN
9100 REM ROW TITLES
9110 LS$(1)="VENTILATION"
9120 LS$(3)="FABRIC LOSSES"
9130 LS$(4)="SOLID WALL"
9140 LS$(5)="GLAZED WALL"
9150 LS$(6)="SOLID ROOF"
9160 LS$(7)="GLAZED ROOF"
9170 LS$(8)="BASE"
9180 RETURN
9200 REM FAB & VENT LOSSES DET.
9210 ML$(M,1)=STR$(INT(X(N,M)/1000))
9220 ML$(M,2)=STR$(INT(X(N,M)*10000/SK)/100)
9230 ML$(M,3)=STR$(INT(X(N,M)*UC))
9240 ML$(M,4)=STR$(INT(X(N,M)*UC*10000/SP)/100)
9290 RETURN

READY.
```

```
100 PRINT"♥":PRINT:PRINT:
110 PRINT" READ DATA FROM FILE (Y/N) ";:INPUTASK$:PRINT
120 IF ASK$="Y"THENGOSUB5000:PRINT
121 PRINT" FUEL DATA DETAIL (Y/N)";:INPUTDD$
122 IFDD$="N"THENGOTO420
123 GOSUB3500
125 PRINT"♥":PRINT:PRINT" ENTER INDIVIDUAL MOLE FRACTIONS FOR":PRINT
126 PRINT" EACH HYDROCARBON PRESENT IN FUEL (I) ":PRINT
127 PRINT" OR ENTER DETAILS RE. EQUIVALENT HYDRO-":PRINT    :PRINT " CARBON FUEL
 (E)
128 PRINT
129 PRINT"                    "CH$
131 PRINT"C ENTER I OR E ";:INPUTCH$
133 IFCH$="I"THENGOTO200
135 IFCH$="E"THENGOTO2000
140 GOTO128
200 PRINT"♥":PRINT
210 PRINT"   **** FUEL ANALYSIS **** ":PRINT:PRINT
220 PRINT"                      "X1
221 PRINT"C CH4    MOLE FRACTION";:INPUTX1:PRINT
222 PRINT"                      "X2
223 PRINT"C C2H6   MOLE FRACTION";:INPUTX2:PRINT
224 PRINT"                      "X3
225 PRINT"C C3H8   MOLE FRACTION";:INPUTX3:PRINT
226 PRINT"                      "X4
227 PRINT"C C4H10  MOLE FRACTION";:INPUTX4:PRINT
228 PRINT"                      "X5
229 PRINT"C C5H12  MOLE FRACTION";:INPUTX5:PRINT
240 A0=X1+X2+X3+X4+X5
250 A=(X1+2*X2+3*X3+4*X4+5*X5)/A0
260 B=(4*X1+6*X2+8*X3+10*X4+12*X5)/A0
280 PRINT"                        "A1
290 PRINT"C N2 MOLE FRACTION        ";:INPUTA1:PRINT
300 PRINT"                        "A2
310 PRINT"C H2O MOLE FRACTION       ";:INPUTA2 :PRINT
320 PRINT"                        "A3
330 PRINT"C O2 MOLE FRACTION        ";:INPUTA3 :PRINT
340 PRINT"                        "A4
350 PRINT"C CARBON MOLE FRACTION    ";:INPUTA4 :PRINT
360 PRINT"                        "A5
370 PRINT"C H2 MOLE FRACTION        ";:INPUTA5 :PRINT
380 PRINT"                        "A6
390 PRINT"C SULPHUR MOLE FRACTION   ";:INPUTA6 :PRINT
400 PRINT"                        "A7
410 PRINT"C CO2 MOLE FRACTION       ";:INPUTA7 :PRINT
414 PRINT"                                "HH
415 PRINT"C HIGHER HEATING VALUE  OF FUEL";:INPUTHH
416 IFCH$="E"THENGOTO2200
420 WF=A0*(12*A+B)+A1*28+A2*18+A3*32+A4*12+A5*2+A6*64+A7*44
440 CPF=16*X1*.532+30*X2*.418+44*X3*.59+58*X4*.406+72*X5*.63+28*A1*.248
```

```
445 CPF=CPF+18*A2*.445+32*A3*.219+12*A4*.171+2*A5*3.42+64*A6*.176+44*A7*.201
446 CPF=CPF/WF
465 SUM=169297*(A0*A+A4+A7)+61485*(A0*B+2*A2+2*A5)+127744*A6
466 HF=HH-SUM/WF
500 PRINT:PRINT:
510 PRINT"                                  "PO
520 PRINT"C % OXYGEN IN FLUE GAS    ";:INPUTPO:PRINT
530 R=(PO/100)/(1-PO/100)
540 H=(1+R)*(A0*A+A4+A7+2*A6)+A5/2+A0*B/4-A7-A3+A1/3.76 :H=-H/(R-1/3.76)
550 SA=(H-A1)/3.76
560 G=R*(A0*A+A4+A7+H+2*A6)
570 PRINT"                                  "T1
580 PRINT"C FUEL TEMPERATURE (F)    ";:INPUTT1:PRINT
590 PRINT"                                  "T2
600 PRINT"C AIR  TEMPERATURE (F)    ";:INPUTT2:PRINT
610 PRINT"                                  "TFG
620 PRINT"C FLUE GAS TEMPERATURE(F)";:INPUTTFG:PRINT
630 PRINT"                                  "W2
640 PRINT"C AIR SPECIFIC HUMIDITY   ";:INPUTW2:PRINT
650 H1=HF+CPF*(T1-77)
660 H2=(4.76*SA*28.96/WF)*(.24*(T2-77)+W2*(.445*(T2-77)-5779))
665 D=A0*A+A4+A7:K=2*A6:J=A5+A2+A0*B/2
670 C1=(D+G+H+2*A6)*(44*D+32*G+28*H+64*K)/((D+G+H+K)*WF)
680 B1=(-3847*D*44-1996*K*64)/(44*D+32*G+28*H+64*K)+.25*(TFG-77)
690 B2=(J*18/WF)*(-5779+.445*(TFG-77))
700 H3=C1*B1+B2
710 EF=(ABS(H3)-ABS(H1+H2))*100/HH
715 PRINT:PRINT"   ┌──────────────────────────────┐"
720 PRINT"         EFFICIENCY     = ";(INT(EF*100))/100
730 AF=4.76*SA*28.96/WF
740 AT=(AF/SA)*(A0*(A+B/4)-A3+A4+A5/2+2*A6)
750 EA=(AF-AT)*100/AT
760 CO2=D*100/(D+G+H+K)
780 PRINT:PRINT"         EXCESS AIR (%) = ";(INT(EA*100))/100
790 PRINT:PRINT"         CO2        (%) = ";(INT(CO2*100))/100
795 PRINT:PRINT"   └──────────────────────────────┘":PRINT
1000 PRINT:PRINT" FILE DATA (F)":PRINT:PRINT" REVIEW FUEL DETAILS (R)
1001 PRINT:PRINT" HARDCOPY RESULTS (H)"
1002 PRINT:PRINT" REPEAT CALCULATION (RET)"
1003 FD$=""
1004 PRINT:PRINT" INPUT F,R,H OR RET ";:INPUTFD$
1005 IF FD$="F"THENGOSUB4000
1006 IF FD$="H"THENGOSUB3000
1008 IF FD$="R"THENGOTO125
1010 IF FD$=""THENGOTO500
1020 GOTO1000
2000 PRINT"C":PRINT
2005 PRINT" ****EQUIV.HYDROCARBON FUEL DATA ****":PRINT
2010 PRINT"                                  "A0
2020 PRINT"C ENTER ALPHA FOR FUEL     ";:INPUTA0:PRINT
2030 PRINT"                                  "A
2040 PRINT"C NO OF CARBON ATOMS       ";:INPUTA:PRINT
```

```
2050 PRINT"                                   "B
2060 PRINT"C NO OF HYDROGEN ATOMS    ";:INPUTB:PRINT
2070 GOTO280
2200 PRINT"♥":PRINT
2205 PRINT" ****EQUIV.HYDROCARBON FUEL DATA ****":PRINT
2210 PRINT"                                   "WF
2220 PRINT"C MOLECULAR WEIGHT                 ";:INPUTWF:PRINT
2230 PRINT"                                   "CPF
2240 PRINT"C SPECIFIC HEAT                    ";:INPUTCPF:PRINT
2250 PRINT"                                   "HF
2260 PRINT"C ENTHALPY OF FORMATION            ";:INPUTHF:PRINT
2270 GOTO500
3000 REM HARDCOPY ROUTINE
3100 OPEN1,4:R$=CHR$(16)
3110 PRINT#1,CHR$(14)R$"10COMBUSTION EFFICIENCY TEST";CHR$(15):PRINT#1:PRINT#1
3120 PRINT#1,R$"10BOILER TYPE";R$"36";BT$
3130 PRINT#1,R$"10BOILER CAPACITY";R$"36";BC$
3140 PRINT#1,R$"10BOILER NUMBER";R$"36";BN$:PRINT#1
3150 PRINT#1,CHR$(14)R$"10INPUT";CHR$(15):PRINT#1
3160 PRINT#1,R$"10AIR  TEMPERATURE ";R$"35";T2;R$"42F"
3170 PRINT#1,R$"10FUEL  TEMPERATURE ";R$"35";T1;R$"42F"
3180 PRINT#1,R$"10FLUE GAS TEMPERATURE ";R$"35";TFG;R$"42F"
3190 PRINT#1,R$"10FLUE GAS OXYGEN CONC ";R$"35";PO;R$"42%":PRINT#1
3200 PRINT#1,CHR$(14)R$"10OUTPUT";CHR$(15):PRINT#1
3210 PRINT#1,R$"10COMBUSTION EFFICIENCY   ";R$"35";(INT(EF*100))/100;R$"42%"
3220 PRINT#1,R$"10EXCESS AIR ";R$"35";(INT(EA*100))/100;R$"42%"
3230 PRINT#1,R$"10FLUE GAS CO2  ";R$"35";(INT(CO2*100))/100;R$"42%"
3300 RETURN
3500 REM BOILER SPECS SUBROUTINE
3510 PRINT"♥":PRINT:PRINT
3520 PRINT"                    "BT$
3530 PRINT"C BOILER TYPE      ";:INPUTBT$:PRINT
3540 PRINT"                    "BC$
3550 PRINT"C BOILER CAPACITY ";:INPUTBC$:PRINT
3560 PRINT"                    "BN$
3570 PRINT"C BOILER NUMBER    ";:INPUTBN$:PRINT
3600 RETURN
4000 PRINT"♥":PRINT:PRINT" FILE NAME ";:INPUTF$
4010 OPEN15,8,15
4020 OPEN2,8,2,"@0:"+F$+",S,W
4031 PRINT#2,X1
4032 PRINT#2,X2
4033 PRINT#2,X3
4034 PRINT#2,X4
4035 PRINT#2,X5
4040 PRINT#2,A1
4041 PRINT#2,A2
4042 PRINT#2,A3
4043 PRINT#2,A4
4044 PRINT#2,A5
4045 PRINT#2,A6
4046 PRINT#2,A7
```

```
4047 PRINT#2,HH
4048 PRINT#2,T1
4049 PRINT#2,T2
4050 PRINT#2,TFG
4051 PRINT#2,PO
4052 PRINT#2,W2
4053 PRINT#2,AO
4054 PRINT#2,A
4055 PRINT#2,B
4056 PRINT#2,WF
4057 PRINT#2,CPF
4058 PRINT#2,HF
4059 PRINT#2,CH$
4060 PRINT#2,BT$
4061 PRINT#2,BC$
4062 PRINT#2,BN$
4200 CLOSE2:CLOSE15:RETURN
5000 PRINT"♥":PRINT:PRINT" FILE NAME ";:INPUTF$
5010 OPEN15,8,15
5020 OPEN2,8,2,"@O:"+F$+",S,R
5031 INPUT#2,X1
5032 INPUT#2,X2
5033 INPUT#2,X3
5034 INPUT#2,X4
5035 INPUT#2,X5
5040 INPUT#2,A1
5041 INPUT#2,A2
5042 INPUT#2,A3
5043 INPUT#2,A4
5044 INPUT#2,A5
5045 INPUT#2,A6
5046 INPUT#2,A7
5047 INPUT#2,HH
5048 INPUT#2,T1
5049 INPUT#2,T2
5050 INPUT#2,TFG
5051 INPUT#2,PO
5052 INPUT#2,W2
5053 INPUT#2,AO
5054 INPUT#2,A
5055 INPUT#2,B
5056 INPUT#2,WF
5057 INPUT#2,CPF
5058 INPUT#2,HF
5059 INPUT#2,CH$
5060 INPUT#2,BT$
5061 INPUT#2,BC$
5062 INPUT#2,BN$
5200 CLOSE2:CLOSE15:RETURN

READY.
```

```
10 VM=1
20 DIM KV(7,50),Y(50)
100 DN=0:PRINT"READ DATA FROM FILE (Y/N)";:INPUTA1$
110 IFA1$="Y"THENGOSUB3000
120 PRINT:PRINT"REVIEW DATA (Y/N)";:INPUTRD$
125 IFRD$="N"THENGOTO160
150 GOSUB1000
160 PRINT"DO YOU WISH TO:-":PRINT
165 PRINT" (1) OUTPUT TO SCREEN  (S)":PRINT
170 PRINT" (2) OUTPUT TO PLOTTER (P)":PRINT
180 PRINT" ENTER S OR P";:INPUTCH$
185 GOSUB2100
190 IFCH$="S"THENGOSUB4000
200 IFCH$="P"THENGOSUB5000
500 STOP
1000 DN=0
1090 PRINT""
1094 PRINT"    ";DE$
1095 PRINT"    DATA DESCRIPTION"
1096 INPUT" ";DE$:PRINT
1100 PRINT"                         "ND
1110 PRINT" ENTER NUMBER OF DAYS";:INPUTND:PRINT
1120 PRINT"                         "IV
1130 PRINT" READING INTERVAL(HRS)";:INPUTIV
1140 NI=24/IV
1150 PRINT:PRINT" ENTER POWER READINGS IN:":PRINT
1160 PRINT" (A) KW "
1170 PRINT" (B) MW ":PRINT
1175 PRINT"                    ";Q2$
1180 PRINT" ENTER A OR B";:INPUTQ2$
1190 IFQ2$="B"THENVM=1000
1200 IFQ2$<>"A"ANDQ2$<>"B"THENGOTO1150
1205 DN=DN+1
1210 PRINT"DAY NUMBER ";DN
1215 PRINT:PRINT"    TIME              KW "
1220 IFQ2$="B"THENPRINT"";TAB(22);"MW"
1230 PRINT
1240 N=0:TM=0
1250 N=N+1:TM=TM+IV
1260 PRINTTAB(4);TM;TAB(21);KV(DN,N)
1270 PRINTTAB(20);"";:INPUTKV(DN,N)
1280 IFN<>NITHENGOTO1250
1290 PRINT"DAY NUMBER ";DN;" ENDED"
1295 PRINT:N$="N":PRINT"                                ";N$
1300 PRINT"  ANY ERRORS (Y/N/J)";:INPUTAE$
1310 IFAE$="Y"THENGOTO1210
1320 IFAE$="J"THENGOTO1350
1330 IFAE$<>"N"THENGOTO1300
1340 IFDN<>NDTHENGOTO1205
```

```
1350 PRINT:PRINT"  END OF INPUT-FILE DATA (Y/N)";:INPUTFD$
1360 IFFD$="Y"THENGOSUB2000
1370 IFFD$<>"N"ANDFD$<>"Y"THENGOTO1350
1380 PRINT"HARDCOPY DATA (Y/N)";:INPUTHC$
1390 IFHC$="N"THENRETURN
1400 OPEN1,4:R$=CHR$(16)
1410 FORI=1TOND:FORJ=1TONI
1420 IFKV(I,J)=0THENGOTO1440
1430 PRINT#1,"     ";I;R$"10";J;R$"20";KV(I,J):NEXT:NEXT
1440 CLOSE1
1900 RETURN
2000 REM FILE DATA ROUTINE
2010 PRINT:PRINT"  INPUT FILE NAME ";:INPUTF$
2020 OPEN15,8,15
2025 OPEN2,8,2,"@0:"+F$+",S,W
2030 PRINT#2,ND:PRINT#2,IV:PRINT#2,Q2$  :NI=24/IV:PRINT#2,DE$
2040 FORI=1TOND:FORJ=1TONI:
2050 PRINT#2,KV(I,J):NEXT:NEXT
2060 CLOSE2:CLOSE15:RETURN
2100 REM DET MAX DATA IN STAND.FORM:MX=0
2105 PRINT""
2110 FORI=1TOND:FORJ=1TONI
2120 IFKV(I,J)>MXTHENMX=KV(I,J)
2125 NEXT:NEXT
2130 FORN=1TO10
2140 IFMX>10↑NANDMX<10↑(N+1)THENGOTO2160
2150 NEXTN
2160 EX=N
2170 IFMX<9*10↑EXTHENMY=9
2175 IFMX<6*10↑EXTHENMY=6
2180 IFMX<4*10↑EXTHENMY=4
2185 IFMX<3*10↑EXTHENMY=3
2190 IFMX<2*10↑EXTHENMY=2
2200 RETURN
3000 REM READ  FILE DATA ROUTINE
3010 PRINT:PRINT"  INPUT FILE NAME ";:INPUTF$
3020 OPEN15,8,15
3025 OPEN2,8,2,"@0:"+F$+",S,R
3030 INPUT#2,ND:INPUT#2,IV:INPUT#2,Q2$  :NI=24/IV:INPUT#2,DE$
3040 FORI=1TOND:FORJ=1TONI:
3050 INPUT#2,KV(I,J):NEXT:NEXT
3060 CLOSE2:CLOSE15:RETURN
4000 REM OUTPUT TO SCREEN ROUTINE-USES SINONS BASIC
4040 HIRES 0,1
4050 LINE 24, 5,24,185,1
4060 LINE 24, 185,315,185,1
4070 LINE 24, 186,315,186,1
4080 SU=185:IC=180/MY
4090 FORLL=1TOMY:SU=SU-IC:LINE 24,SU,26,SU,1:CHAR 10,SU,LL+48,1,1:NEXT
4100 TEXT 30,5,"MW X 10↑",1,1,8
4110 CHAR 98,5,EX+48,1,1:M=-1
4120 FORN=1TO13:CA=24*N-3:M=M+1
```

```
4130 IFM=5THENM=0
4140 IFN>=6ANDN<11THENGOSUB4600
4150 IFN>=11THENGOSUB4650
4160 PC=48+M*2
4170 CHAR CA,192,PC,1,1:NEXT
4172 FORI=1TOND
4174 Y(1)=180*KV(I,1)/(MY*10↑EX):Y(1)=185-INT(Y(1))
4176 PLOT 24+12,Y(1),1
4178 REM****MODIFY 4180-4200 IF NOT HOURLY INCREMENTS*****
4180 FORJ=2TONI
4185 X=24+12*J:Y(J)=180*KV(I,J)/(MY*10↑EX):Y(J)=185-INT(Y(J))
4190 DY=(Y(J)-Y(J-1))/12
4195 FORZ=11TO0STEP-1
4197 Y=Y(J)-Z*DY
4200 PLOT X-Z,Y,1
4210 NEXTZ
4220 NEXTJ
4230 NEXTI
4500 GETC$:IFC$=""THENGOTO4500
4510 IFC$="C"THENCOPY
4550 NRM:RETURN
4600 CHAR CA-7,192,49,1,1:RETURN
4650 CHAR CA-7,192,50,1,1:RETURN
5000 REM ROUTINE FOR PLOTTER PET ONLY
5010 FORI=1TOND:READDAY$(I):NEXT
5020 DATA "SAT","SUN","MON","TUE","WED","THUR","FRI"
5030 OPEN5,5:POKE1020,128
5040 PRINT"▒":PRINT"▒▒▒▒▒▮▮▮    PLOTTER CHECK"
5042 PRINT:PRINT"         (1)  PLOTTER ON?"
5043 PRINT:PRINT"         (2)  PAPER IN?"
5044 PRINT:PRINT"         (3)  PEN NUMBERS?":PRINT
5045 PRINT"              PEN 2 FINE BLACK
5046 PRINT"              PENS 1,3,4,5,6 COLOURS
5047 PRINT"▒▒▮▮    TO PLOT-PRESS RETURN":PRINT
5048 GETC$:IFC$=""THENGOTO5048
5055 PRINTTAB(6);"▒*PLOTTING CURVES":PRINT
5070 PRINT#5,"IN;RO90;IP420,3000,7200,6500;SC-3,27,0,";MY;";"
5080 PRINT#5,"SP2;PUPA0,";MY;"PD0,0,24,0;"
5090 PRINT#5,"PU;TL1,0;SI.1,.2;"
5100 FORX=1TO24
5110 PRINT#5,"PUPA";X;",0;XT;":NEXT
5120 FORX=0TO24STEP2
5130 PRINT#5,"PUPA";X;",0;CP-1.5,-1;LB";X;"";CHR$(3):NEXT
5140 FORY=1TOMY
5150 PRINT#5,"PUPA0,";Y;";YT;":NEXT
5155 FORY=0TOMY
5160 PRINT#5,"PUPA0,";Y;";CP-3,-.25;LB";Y;"";CHR$(3):NEXT
5170 Q$=" MW X"+STR$(10↑EX)
5180 PRINT#5,"SI.15,.2;PUPA0,";MY;";CP1.5,-.3;LB";Q$;"";CHR$(3)
5190 S$="TIME"
5200 PRINT#5,"PUPA24,0;CP-4,1;LB";S$;"";CHR$(3)
5210 REM PLOT CURVES
```

```
5220 FORI=1TOND:P=I:IFP=7THENP=1
5230 IFI>2THENPRINT#5,"SP";P;";PU;"
5240 FORJ=1TO24:Y(J)=KV(I,J)/10↑EX:NEXT
5250 FORJ=2TO24:K=J-1
5260 PRINT#5,"PA";K,Y(K);";PD";J,Y(J);";":NEXTJ:PRINT#5,"PU;":NEXTI
5270 REM DESCRIPTION BOX
5280 PRINT#5,"IN;RO90;IP;IW;SC-5,27,-40,15;SP2;"
5290 T$="DAILY POWER VARIATION "+DE$
5300 PRINT#5,"SI.2,.3;PUPA0,14;CP0,-.5;LB";T$;"";CHR$(3)
5310 PRINT#5,"PUPA0,0PD0,8,9,8,9,0,0,0;SI.15,.15;"
5320 FORI=1TOND:P=I:IFP=7THENP=1
5330 IFI>2THENPRINT#5,"SP";P;";PU;"
5335 VP=8-I
5340 PRINT#5,"PUPA1,";VP;"PD4,";VP;"PU;":NEXTI
5350 PRINT#5,"SP2"
5360 FORI=1TOND:VP=8-I:PRINT#5,"PUPA6,";VP;";CP0,-.2;LB";DAY$(I);"";CHR$(3)
5365 NEXTI
5370 PRINT#5,"IP;SP0;"
5380 CLOSE5
5390 PRINTTAB(6);"■*CURVES PLOTTED":PRINT
5400 RETURN
```

APPENDIX B

A listing of the computer program BOILER used in the detailed analysis of energy use as described in chapter five is printed in this appendix.

```
common shared vm,s,bnp$,otc
dim shared xp(100),yp(100),eff(5,100),feff(5,100)
dim                                                        shared
r(51,100),f(51,100),tm%(100),ch$(10),fs$(100),yf(100)
dim max(12),teff(100),boil(5),fteff(100)
dim dayw$(7),dir$(5),yfp(100)

key 1," END "
key 2," MAIN"
key 3," PREV"

fdyyr=1          :rem  1st day of yr is  day  1  Sun(day
1=Sun) for 1989 /1988 is day 6
gaspr=.162      :rem price of gas pence per therm
calval=1.016    :rem calorific val in therms per 100scf

fc%=1:lc%=35:si=900:fr=100:fh=fr*si:cp$="4":nf=1:nfm=0
:css$="n":ss$="n"
max(1)=31:max(2)=28:max(3)=31:max(4)=30:max(5)=31
:max(6)=30:max(7)=31:max(8)=31
max(9)=30:max(10)=31:max(11)=30:max(12)=31
dayw$(1)="Sun":dayw$(2)="Mon":dayw$(3)="Tue"
:dayw$(4)="Wed":dayw$(5)="Thu"
dayw$(6)="Fri":dayw$(7)="Sat"
dir$(1)="N":dir$(2)="W":dir$(3)="S"
:dir$(4)="E":dir$(5)="N"
yr$=right$(date$,2)
if int(val(yr$)/4)=val(yr$)/4 then max(2)=29
dy$=mid$(date$,4,2):mon$=left$(date$,2)
nn=len(str$(nf)):st$=right$(str$(nf),nn-1)
fn$="BR"+dy$+mon$+st$+".dat"
solc=31:rhc=33:otc=32                           '  solar,  rh
and o/side temp chans
k1=.623:k2=.00752:k3=1299                       ' boiler  eff
constants
rmon$=mon$:rdy$=dy$:gosub  150:cdywk=dywk ' get day  of
week:
90 t%=0:ln%=0:lgon%=0:timer off
main:
100 screen 0
cls:ip%=0:men=1:a$=""
if ko=1 then key on
if ko=0 then key off
print"MAIN                                                  MENU
PRESS"
print
if  sd%=1 then print"          *** SCAN ENDED  -  DATA
FILED AT ";FT$;"  ***"
print"LOG      -    Start logging  with  screen  display
L"
print"         -    Examine /  Change  current  settings
E"
print"          -     Monitor   logging   in    progress
M"
print"          -     Abort   logging   and   file   data
```

```
A"
print
print"TREND          -        Display      Current       Data
D"
print"               -        Display       Filed        Data
F"
print"               -        Exchange      Filed        Data
X"
print
print"MODE                -              Screen          Save
V"
print"                    -              Key            on/off
K"
print"          -    Go  to  DOS "
print
rem      print"CHANN       -        Channel        Options
C":print
if lgon%=0  then print"STATUS -   LOGGING OFF "
if lgon%=1  then print"STATUS -   LOGGING ON "
if filedat$="y" then print"          -    ";file$;" LOADED"
if sd%=2 and nfm<>0 then gosub 220
print:print"ENTER SELECTION"
110 a$=inkey$
wn=val(a$):on wn goto 200,main,300
if a$="l" then goto 1000
if a$="m" then goto 2500
if a$="e" then goto 1600
if a$="d" then goto 6000
if a$="f" then goto 400
if a$="x" then goto 350
if a$="a" then goto 200
if a$="k" then goto 120
if a$="v" then goto 130
if a$="j" then goto 135
goto 110
120 if ko=1 then goto 125
    ko=1:goto main
125 ko=0:goto main

130 cls:key off: ko=1                                   ' screen
save
132 ssa$=inkey$
    wn=val(ssa$):on wn goto 200,main,300
goto 132

135 pr$=inkey$:if pr$="o" then goto 136
    if pr$="" then goto 135
    goto main
136 ps$=inkey$:if ps$="h" then goto 137
    if ps$="" then goto 136
    goto main
137 pt$=inkey$:if pt$="n" then goto 140
    if pt$="" then goto 137
    goto main
140 rem go to DOS
    cls
```

```
    if lgon%=0 then goto 141
    edos                      =timer:nextscan=(si-(edos-
scantime))/60:nextscan=int(10*nextscan)/10
    print"NEXT SCAN IN ";nextscan;" MINUTES":print
141 print"type EXIT to return from DOS":print
    shell
    if lgon%=0 then goto main
    idos=timer:sit=si-(idos-scantime)
142 if sit>0 then goto 143 else sit=sit+si
    goto 142
143 on timer(sit) gosub 4000
    goto main

150 rem find day of week held in dayw$(dywk)
    ndys=0:dywk=fdyyr-1:if dywk=0 then dywk=7
    if val(rmon$)>1 then lm=val(rmon$)-1 else goto 160
    for n=1 to lm:ndys=ndys+max(n);next n
160 ndys=ndys+val(rdy$)
    for n=1 to ndys:dywk=dywk+1
    if dywk=8 then dywk=1
    next n
return

200  cls:locate 12,25:print"DO YOU WISH TO END  PROGRAM
Y/N"
210 ed$=inkey$
    wn=val(ed$):on wn goto 200,main,300
    if ed$="y" and a$="a" then goto 4400
    if ed$="y" then end
    if ed$="n" then goto main
goto 210

220 print"       -    FILES STORED (";nfm;")   ";
    for fa=1 to nfm:print fs$(fa);"  ";:next:print
return

300 rem menu backtracking
if men=1 then goto 100
if men=2 then goto 1600
if men=3 then goto 6000
if men=4 then goto 6500
if men=5 then goto 400
if men=6 then goto 6700
if men=7 then goto 6600
if men=8 then goto 6800
goto main
350 rem exchange filed data
men=1:cls:if filedat$="y" then goto 402
print:print:print"There    is    no    file    currently
loaded":print
print"PRESS  3  TO RETURN TO MAIN MENU"
idlefe:
      cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idlefe

400 rem read filed data
```

```
choice$="f":if filedat$="y" then goto 6000
men=1:cls
402 choice$="f"
print"LOAD FILED DATA FOR DISPLAY";tab(75);"PRESS":print:print
print"LIST ALL DATA FILES";tab(77);"L":print
print"SELECT & LOAD  FILE";tab(77);"S":print
403 c$=inkey$
    wn =val(c$):on wn goto 200,main,300
    if c$="L" or c$="l" then gosub 500
    if c$="S" or c$="s" then goto 600
    c$=""
goto 403
405 print"LOADING DATA FROM ";file$:print
  open file$ for input as #1
  input #1,fstart$
  input #1,ffin$
  input #1,ffc%:input #1,flc%:input #1,ffr:input #1,fsi
  for ft% = 1 to ffr
      for s = ffc% to flc%
      f(s,ft%)=0:rem clean any existing data to 0:
      input #1,f(s,ft%)
      next s
  next ft%
  close #1
filedat$="y":fibo=0:tempcall=0:rem eff & temp routines reinvoked
rdy$=mid$(file$,3,2):rmon$=mid$(file$,5,2):gosub 150:fdywk=dywk
print"Data loaded": print:print"PRESS RETURN TO CONTINUE"
410 a$=inkey$
    wn=val(a$):on wn goto 200,main,300
    if a$="" then goto 410
goto 6000
450 print"File cannot  be  found":print
print"PRESS 3 FOR MAIN MENU":
idlefw:
     cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idlefw
500 if c$="l" then cls:
    print"CURRENT DATA FILES ON DISC":print:print
    men=5
    print"NUMBER";tab(15);"DAY";tab(30);"DATA FILE NAME":print
    shell "dir.dat > dirfile"
    open "dirfile" for input as #1
    num%=1
    while not eof(1)
    line input #1,tmp$
    if instr(tmp$,"DAT") then gosub 550
    wend
    nodir=num%-1
    close #1:print:print
    if num%=1 then print"NO DATA FILES ON CURRENT DISC"
return
```

```
550
rdy$=mid$(tmp$,3,2):rmon$=mid$(tmp$,5,2)
:ryr$=mid$(tmp$,30,2)
     gosub 150
     print num%;tab(15);dayw$(dywk);tab(30);tmp$
     num%=num%+1
return
600 cls:print:print
     gosub 500
     men=5
     tempf$=file$
     input;"ENTER   FILE   NUMBER";numb:print
     if numb<1 or numb>nodir then goto 610
     shell "dir.dat > dirfile"
     open "dirfile" for input as #1:num%=1
     while not eof(1)
      line input #1,tmp$
      if instr(tmp$,"DAT") and  numb=num% then goto 605
      if instr(tmp$,"DAT") then num%=num%+1
     wend
605 close #1
     file$=left$(tmp$,7)+".DAT":print
     if file$<>"" then goto 405
610 print: print"FILE DOES NOT EXIST"
     file$=tempf$
idlesf:
     cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idlesf
900 rem output to GPIB:
     call absolute(addr%,st$,iooutput%)
     return
1000 ip%=1:sd%=0:a$=""
men=1
if lgon%=1 then goto 100
gosub 1050
gosub 1500
cls:print"ENTER OPTIONS":print
print"Logging may be started immediately  OR  it may be
delayed to
print"start at a later time.":print
print"Enter I to start immediately  OR"
print"Enter D to start at delayed time":print
print"PRESS  3 TO RETURN TO MAIN MENU"
1010 b$=inkey$
wn=val(b$):on wn goto 200,main,300
if b$="I" or b$="i" then goto 2000
if b$="D" or b$="d" then goto 3000
goto 1010

1050 'initialise & check serial radio link
      open "com1:4800,n,8,2,asc" as #3
      pca$=chr$(1):pcb$=chr$(2):pcc$=chr$(3)
:pcd$=chr$(4):pce$=chr$(5)
1060 print #3,pce$                                     'clear
interface and ...
```

```
     rep1$=input$(1,#3):rep1=asc(rep1$)
     print "Waiting for Nak (ascii 21) ----------------
actual reply is ";rep1
     if  rep1<>21 then goto  1060                    'wait
for NAK (ASCII 21)
close #3
return

1100  'get PACS radio link data, convert & allocate  to
array r( , )
     open "com1:4800,n,8,2,asc" as #3
     cmd$=pca$+"RD"+pcb$+"00001F"+pcc$+"61"+pcd$
'command to PACS master
     rl=200
'reply string length
1140                    print                        #3,cmd$
'send command
1141 rep2$=input$(1,#3)
1142 rep2=asc(rep2$)
rem     print "Waiting for Ack (ascii 6) -------------
---  actual reply is ";rep2

1143      if      rep2<>6      then      goto      1140
'ASCII 6 = Ack
1144                                  rep$=input$(rl,#3)
'get reply
1145 rep=asc(rep$)
rem     print "Waiting for 1st char=1 for valid data --
- actual 1st char is ";rep
1146      if      rep<>1      then      goto      1140
'repeat if no good
     gosub                                            1150
'split rep$ string & convert
     close #3
return

1150 for n=1 to 32
       stst=5+(n-1)*6
       valu$=mid$(rep$,stst,6):gosub 1160
       if    n>8   and   n<17   then    r(n+27,t%)=valu
'allocate PACS temp channs 9-16
     next   n                                          'to
software channs  36-43
return

1160
'convert hex string to dec
    valu=0
    for m=3 to 6
    ch$=mid$(valu$,m,1)
    digit=val(ch$)
    if asc(ch$)>60 then digit=asc(ch$)-55
    valu=valu+digit*16^(6-m)
    next m
    if  n>8 and n<17 then gosub 1170                 'temp
conversion
```

```
rem    if n>24         then gosub 1170
return

1170 valu=valu*275/4095-25
1171 valu=int(100*valu)/100
return

1500 def seg=&ha000:enter%=6
     devclr%=15:addr%=5:call absolute(addr%,devclr%)
     iooutput%=3:init%=0:myaddr%=21
:ioport%=&h2b8:setting%=&h0100
     call absolute(ioport%,myaddr%,setting%,init%)
     day$=mid$(date$,4,2)+"-"+left$(date$,2)+"-
"+right$(date$,2)
     t$=left$(time$,5)
     st$="HA"
:gosub 900
     st$="IN              DA                   "+day$
:gosub 900
     st$="IN               TI                    "+t$
:gosub 900
     st$="CH          1-40          SE           114"
:gosub 900:rem 0-10V:
     st$="CH"+str$(solc)+"         SE           112"
:gosub 900:rem 0-100mV:
     st$="TA   1   OP   ME   TR   TI   DE   0   CO   1"
:gosub 900
     st$="TA  1  CH  1-40 AT F LO EV FO  CO  MA  NO  TO
GP":gosub 900
return

1600 cls:print"CURRENT  SETTINGS":print
men=1:a$=""
print"Monitored channels     First    ";fc%
print"                       Last     ";lc%
print"                       Option    ";ch$(val(cp$))
print"Data  Scan Interval              ";si;tab(43);"
secs"
    fh=(fr-1)*si:print
print"LOGGING                MODE                OPTIONS
CHOSEN"
    pfr=fr
    if css$="n" then pfr=0
    if css$="n" and lgon%=0 then gosub 2400
    mfr=fr
    if css$<>"n" then mfr=0
    pfh=pfr*si
print"Single  period     -    file   after    ";pfr;"
readings"
print"                        after ";pfh;" seconds"
print"Multiple  periods    -    file   every    ";pfr;"
readings"
print"                        every ";pfh;" seconds"
print"Multiple periods  -  file at midnight "
print"                          after       ";mfr;"
readings"
```

```
print"CURRENT     STATUS"
print"Date
";dayw$(cdywk);" ";dy$+"-"+mon$+"-"+yr$
ct$=left$(time$,2)+mid$(time$,4,2)
print"Current       Time                   ";ct$
if lgon%=1 then tart$=start$
print"Scan  started   at                   ";tart$
print"Last   reading  No                  ";lr%
print"                at                   ";tc$
nn=len(str$(nf)):st$=right$(str$(nf),nn-1)
fn$="BR"+dy$+mon$+st$+".dat"
print"Next data file  is                   ";fn$
if lgon%=1 then goto 1605
print:print"ALTER SETTINGS   Y OR N"
gosub 1640
1602 cs$=inkey$
     wn=val(cs$):on wn goto 200,main,300
     if cs$="Y" or cs$="y" then goto 1650
     if cs$="N" or cs$="n" then gosub 1645
goto 1602
1605 print"File  to  disc  at                  ";ft$;
     gosub 1640
idlep:
     cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
     ct$=left$(time$,2)+mid$(time$,4,2)
     locate 17,35:print ct$
     locate 19,34:print lr%
     locate 20,35:print tc$
goto idlep
1640 if css$="s" then locate 9,60
     if css$="m" then locate 11,60
     if css$="n" then locate 13,60
     print"****"
return
1645 locate 23,60:print"PRESS 2 FOR MAIN MENU"
return
1650 cls:print:print"CHANGE    SETTINGS":print
men=2
print"Monitored     channels         First         ";fc%
;tab(45);:input;"                       Change to ";s$
if s$<>"" then fc%=val(s$)
print"                                Last          ";lc%
;tab(45);:input;"                       Change to ";s$
if s$<>"" then lc%=val(s$)
print"Data    Scan    Interval                      ";si;"
secs";tab(45);:input;"                      Change to ";s$
if s$<>"" then si=val(s$)
print:print
print"LOGGING OPTIONS":print
print"Current                    option                   -
";ss$:print
print"Single  period     -     file after  x   readings
-   enter Sx"
print"Multiple  periods  -     file every  x   readings
-   enter Mx"
print"Multiple   periods    -     file   at   midnight
```

```
-   enter N"
print:print
input;"ENTER OPTION";ss$
tss$=ss$:tccs$=css$:stl=len(ss$):css$=left$(ss$,1)
if css$="s" or css$="m" then fr=val(right$(ss$,stl-1))
if ss$="" then gosub 1800
print:print tab(60);"PRESS     3  KEY"
print tab(60);"TO VIEW SETTINGS"
idleb:
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idleb
1800 ss$=tss$:css$=tccs$
return
2000 cls:lgon%=1
if css$="n" then gosub 2400 else gosub 2200
print
tab(5);"TIME";tab(13);"EFF";tab(25);"FUEL";tab(37)
;"AIR";tab(49);"FG TEMP";tab(61);"OXYGEN"
print
timer on
gosub 4000
if sd%=2 then goto main
idlels:
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idlels
2100 start$=time$
     start$=left$(start$,2)+mid$(start$,4,2)
:start=60*val(left$(start$,2))+val(right$(start$,2))
return
2200 gosub 2100
     fmin=start+int(fh/60):fin=40*int(fmin/60)+fmin:if
fin >= 2400 then fin = fin -2400
     ft$=str$(fin)
     if fin<1000 then ft$=" "+right$(str$(fin+10000),4)
return
2400 rem determine no of readings for midnight filing
     gosub 2100
     fr=int((1440-start)/(si/60))+1
2420 fh=(fr-1)*si:fmin=start+int(fh/60)
     if (1440-fmin) > 1 then goto 2450
     fr=fr-1
goto 2420
2450 fin=40*int(fmin/60)+fmin
     ft$=str$(fin)
return
2500 cls:ip%=1
if a$<>"m" then goto main
men=1
if lgon%=1 then goto 2505
locate 12,21:print"     ***  NO  LOGGING  IN  PROGRESS
***":print
locate 14,21:print"              PRESS 3 KEY":goto idlec
2505                                              print
tab(5);"TIME";tab(13);"EFF";tab(25);"FUEL";tab(37)
;"AIR";tab(49);"FG TEMP";tab(61);"OXYGEN"
print:f%=20*int(t%/20)+1:f=fc%-1
```

```
for tt% = f% to t% :tr$=str$(tm%(tt%))
print str$(tt%);tab(4);tr$;tab(12);25*r(f+1,tt%)
;tab(24);25*r(f+2,tt%);tab(36);25*r(f+3,tt%);tab(48)
;75*r(f+4,tt%);tab(60);6.25*r(f+5,tt%)
next
idlec:
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idlec
3000 rem delayed start
print
print"Enter the delayed start time as a 6 figure number
eg. 064500"
t$=time$: print
t$=left$(t$,2)+mid$(t$,4,2)+right$(t$,2)
print"Current time is            ";t$:print
3005 input;"Enter delayed start time";a$:print:print
wn=val(as$):on wn goto 200,main,300
dt=3600*val(left$(a$,2))+60*val(mid$(a$,3,2))+
val(right$(a$,2))
ssm=timer:if ssm>dt then goto 3015
print"TIMER COUNTING"
3010 ssm=timer:ssm=int(ssm)
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
if ssm<dt then goto 3010
goto 2000
3015 print"INVALID START TIME ":print
ct$=inkey$:goto 3005
4000 rem scan channels & input data:
     scantime = timer
     on timer(si) gosub 4000
     st$="RU":gosub 900:s%=1
4110 d$=space$(80):call absolute(addr%,d$,enter%)
     if left$(d$,3)="RUN" then gosub 4200
     if left$(d$,1)="C" then gosub 4300
     if s%<lc% then goto 4110
     tc$=left$(time$,2)+mid$(time$,4,2)
     tm%(t%)=val(tc$):tr$=str$(tm%(t%)):lr%=t%
     st$="HA":gosub 900
     gosub 5000:rem calc efficiencies:
     if ip%=1 then gosub 4150
     gosub 1100:rem get PACS radio link data on  channs
>36
return
4150  f=fc%-1
      print
str$(t%);tab(4);tr$;tab(12);25*r(f+1,t%);tab(24)
;25*r(f+2,t%);tab(36);25*r(f+3,t%);tab(48)
;75*r(f+4,t%);tab(60);6.25*r(f+5,t%)
return

4200 tt$=mid$(d$,7,14):rem data logger date&time
     t%=t%+1:ln%=ln%+1:if ln%=21 then gosub 4250
return
4250 ln%=1:if ip%=0 then return
     cls:print
tab(5);"TIME";tab(13);"EFF";tab(25);"FUEL"
```

```
;tab(37);"AIR";tab(49);"FG TEMP";tab(61);"OXYGEN"
     print
return
4300  for n=0 to 3
      s%=val(mid$(d$,20*n+3,3))
      r(s%,t%)=abs(val(mid$(d$,20*n+6,10)))
      if t%=fr and s%=lc% then goto 4400
      next
return
4400 rem save data
     gosub  1100:rem get PACS radio link data for  last
scan
     st$="HA":gosub 900
     cls:print  tab(20);"*******  SAVING  DATA  *******
TIME ";time$
     nfm=nfm+1
     nn=len(str$(nf)):st$=right$(str$(nf),nn-1)
     fn$="BR"+dy$+mon$+st$+".dat"
     lp=len(fn$):fs$(nfm)=left$(fn$,lp-4)
open fn$ for output as #2
  print #2,start$
  print #2,time$
  print #2,fc%;lc%+8;t%;si
  for tt = 1 to t%
      for s% = fc% to lc%+8
    print #2,r(s%,tt)
      next s%
  next tt
close #2
ft$=time$:sd%=1:t%=0:ln%=0
if css$="s" then goto 90
if ed$="y" and a$="a" then goto 90
for cn=1 to 100
    for cr= 1 to 50
  r(cr,cn)=0
    next cr
    tm%(cn)=0
next cn
for cn=1 to 10:xp(cn)=0:yp(cn)=0:next
sd%=2:ip%=1
if css$="m" then nf=nf+1
if css$="m" then goto 2000
4450 timer off
cls:print"WAITING    TO    RESTART    SCANNING    AT
MIDNIGHT":css$="n":ss$="n"
idlews:
    start$=time$:start$=left$(start$,2)+
mid$(start$,4,2)
    start=val(start$)
    if start<15 then goto 4500
    locate 3,1:print"TIME NOW ";start$
goto idlews
4500 if val(dy$)=max(val(mon$)) then gosub 4550
     dy$=str$(val(dy$)+1)
     if  val(dy$)<10  then  dy$="0"+right$(dy$,1)  else
dy$=right$(dy$,2)
```

```
      cdywk=cdywk+1:if  cdywk=8 then cdywk=1:rem  change
 dayofweek
      goto 2000
 4550 if val(mon$)=12 then mon$="0"
      mon$=str$(val(mon$)+1)
      if val(mon$)<10 then mon$="0"+right$(mon$,1)  else
 mon$=right$(mon$,2)
      dy$="0"
      return
 5000 rem calc efficiencies:
      enum=0:eden=0
      for n=1 to 5
    oxch=6*n-1
    oxy=r(oxch,t%)*25/4
    eff(6-n,t%)=0:lod=0
    if oxy>15 then goto 5050 :rem boiler assumed off:
    tfg=r(oxch-1,t%)*300/4
    tair=(r(oxch+1,t%)-.8)*100/3.2
    delt=tfg-tair
    lod=r(oxch-3,t%)/4
    loss=(k1*delt/(20.95-oxy))+k2*(k3+delt)
    if lod>0 then radn=3*.8/lod:rem 3% loss when  lod=.8
 (80,000scfh)
    eff(6-n,t%)=100-(radn+loss)
 5050      enum=enum+eff(6-n,t%)*lod
    eden=eden+lod
      next n
      if eden>0 then teff(t%)=enum/eden
      r(51,t%)=eden*1000*gaspr*calval:rem total cost per
 hr
 return

 6000 rem choose params to display/output
 if a$="d" then choice$="c"
 men=1:
 cls:print:bn=0:bnp$="":bap$="":wif$="":pif$=""
 print"CHOOSE DATA TO DISPLAY / OUTPUT";tab(70);"PRESS"
 print:print
 print"BOILER NO 1";tab(73);"1":print
 print"BOILER NO 2";tab(73);"2":print
 print"BOILER NO 3";tab(73);"3":print
 print"BOILER NO 4";tab(73);"4":print
 print"BOILER NO 5";tab(73);"5":print
 print"ALL BOILERS";tab(73);"A":print
 print"WEATHER INF";tab(73);"W":print
 print"PLANT DATA ";TAB(73);"P":print
 print"MAIN   MENU";tab(73);"M":print

 6010 cdat$=inkey$
 if cdat$="" then goto 6010
 bn=val(cdat$)
 if bn>0 and bn <6 then goto 6500
 if cdat$="a" then goto 6600
 if cdat$="w" then goto 6700
 if cdat$="p" then goto 6800
 if cdat$="m" or bn>5 then goto 300
```

```
goto 6010
6500 rem output for one boiler (1-5):
men=3:cls:bnp$=""
print"DISPLAY        /        OUTPUT        BOILER        NO
";bn;tab(70);"PRESS":print:print
print"SELECT DATA REQUIRED":print
print"Efficiency";tab(73);"E":print
print"Fuel flow";tab(73);"F" :print
print"Air flow";tab(73);"A"  :print
print"Temperature flue gas ";tab(73);"T":print
print"Oxygen flue gas ";tab(73);"O":print
print"Combustion air temperature ";tab(73);"C"
6510 bnp$=inkey$:dl=9:ls=16:bl=165
     wn=val(bnp$):on wn goto 200,main,300
     if bnp$="e" then goto 7000
     if bnp$="f" then goto 7100
     if bnp$="a" then goto 7200
    .if bnp$="t" then goto 7300
     if bnp$="o" then goto 7400
     if bnp$="c" then goto 7450
goto 6510
6600 rem output all boilers
men=3:cls:bap$=""
print"DISPLAY        /        OUTPUT        FOR        ALL
BOILERS";tab(70);"PRESS":print:print
print"SELECT DATA REQUIRED":print
print"TOTAL        FUEL        &        OUTSIDE
TEMPERATURE";tab(73);"F":print
print"TOTAL        COST        &        OUTSIDE
TEMPERATURE";tab(73);"C":print
print"ON/OFF,        EFFICIENCY        &
TEMPERATURE";tab(73);"O":print
rem print"OVERLAY TRENDS";tab(73);"T":print
6605 bap$=inkey$
wn=val(bap$):on wn goto 200,main,300
if bap$="f" then goto 10000
if bap$="c" then goto 10100
if bap$="o" then goto 10300
goto 6605
6700 rem output weather data
men=3:cls:wif$="":print"DISPLAY        WEATHER
DATA";tab(70);"PRESS":print:print
print"SELECT DATA REQUIRED":print
print"Air Temperature";tab(73);"T":print
print"Relative Humidity";tab(73);"R":print
print"Solar Radiation (global)";tab(73);"S":print
print"Wind Speed ";tab(73);"W":print
print"Wind Direction";tab(73);"D":print
6710 wif$=inkey$
     wn=val(wif$):on wn goto 200,main,300
     if wif$="t" then goto 9010
     if wif$="r" then goto 9100
     if wif$="s" then goto 9200
     if wif$="w" then goto 9300
     if wif$="d" then goto 9400
goto 6710
```

```
6800 rem output plant data
men=3:cls:pif$=""
print"DISPLAY PLANT DATA";tab(70);"PRESS":print:print
print"SELECT DATA REQUIRED":print
print"HPHW TEMPS AC HEATING";tab(73);"A":print
print"HPHW TEMPS AC PROCESS";tab(73);"B":print
print"AIR  TEMPS AC BLOCK  ";tab(73);"C":print

6810 pif$=inkey$:dl=9:ls=16:bl=165
     wn=val(pif$):on wn goto 200,main,300
     if pif$="a" then goto 6820
     if pif$="b" then goto 6830
     if pif$="c" then goto 6840
goto 6810
6820 'ac heating
cls:screen  2:locate  1,8:print"HPHW  Temp(C)   AC
HEATING":
vs=40:vm=1/2:dl=9:ls=16:bl=165
goto 9005
6830 'ac process
cls:screen  2:locate  1,8:print"HPHW  Temp(C)   AC
PROCESS":
vs=40:vm=1/2:dl=9:ls=16:bl=165
goto 9005
6840 'ac air temps
cls:screen 2:locate 1,8:print"AIR Temp(C)  AC BLOCK":
vs=5:vm=4:dl=9:ls=16:bl=165
goto 9005
7000 rem efficiency display
cls:screen 2
locate 1,8:print"Efficiency %":vs=5:vm=125
7005 men=4:bl=165
if choice$="f" then gosub 7500
locate      1,35      :print"Boiler       #";bn:locate
23,75:print"Time"
line(41,5)-(41,165):line(41,165)-(617,165):xp=-3
gosub 7030:gosub 7040
if bnp$="t" then goto 7012
if bnp$="e" then goto 7013
7006  for  m=0  to  5:line(41,5+32*m)-(46,5+32*m):  rem
32=160/5
     xp=xp+4:locate xp,1:print vs*(5-m)
next
     for m=0 to 4:line(41,21+32*m)-(43,21+32*m):next

7007 for m=1 to 24:line(41+24*m,165)-(41+24*m,163):next
m
gosub 9020:xp=4
7008  for xn=2 to 24 step 2:nx$=str$(xn):if xn<10  then
nx$=" "+right$(str$(100+xn),2)
     line(41+24*xn,161)-(41+24*xn,163)
     xp=xp+6:locate 22, xp:print nx$
next
gosub 7030:gosub 7040
if choice$="f" then goto 7020
```

```
7009 last=lr%
      for t=1 to lr%
   call plot(t,start,r(s,t),dummy)
      next t

7010      if      lr%>last      then      last=t%:call
plot(last,start,r(s,t%),dummy)
      cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
      tn$=left$(time$,2)+mid$(time$,4,2):locate
1,69:print"Time ";tn$
goto 7010


7012 xp=-4:dl=8:ls=20
      for m=0 to 4:line(41,5+40*m)-(46,5+40*m):
      xp=xp+5:locate xp,1:print vs*(4-m)
next
      for m=0 to 3:line(41,26+40*m)-(43,26+40*m):next
goto 7007
7013 xp=-4:dl=9:ls=16
      for m=0 to 4:line(41,5+40*m)-(46,5+40*m):
      xp=xp+5:locate xp,1:print 90-vs*m
next
      for m=0 to 19:line(41,13+8*m)-(43,13+8*m):next
goto 7007

7015
'calculate boiler eff
      sub effplot(x,y,arel,t1) static
      y=165-1.6*vm*(arel-2.8)
      if  choice$="c" then  effel=eff((31-s)/6,t1)  else
effel=feff((31-s)/6,t1)
      yec=165-8*(effel-70)
      pset(x,yec)
end sub

7020
fstrt=60*val(left$(fstart$,2))+val(right$(fstart$,2))
      if  int((s+5)/6)=(s+5)/6   and fibo=0  then  gosub
12000
      for t=1 to ffr
   call plot(t,fstrt,f(s,t),dummy)
      next t

idled:
      cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idled

7024 sub curloop(y,arel,vm) static
   y=165-1.6*vm*(arel-.8)/3.2
end sub

7030 rem choose 1st channel for 5 boilers:
      s=31-6*bn
return
```

```
7040 rem choose channel number s:
     if bnp$="e" then return
     if bnp$="f" then s=s+1
     if bnp$="a" then s=s+2
     if bnp$="t" then s=s+3
     if bnp$="o" then s=s+4
     if bnp$="c" then s=s+5
return

7075 sub plot(t1,strt,arel,effel) static
     x=35+6*(t1+strt/15)
     y=165-1.6*vm*arel
     if  s>31  and s<36  then  call  curloop(y,arel,vm)
'at line 7024
     if bnp$="c"      then call curloop(y,arel,vm)
     if s=otc then y=165-1.6*vm*(arel-1.12)/1.28
     if   bnp$="e"   then   call   effplot(x,y,arel,t1)
'at line 7015
     if  y>0  and  y<200 then  pset(x,y):if  t1>1  then
line(x,y)-(xp(s),yp(s))
     if s=36 then yf=165-1.6*vm*f(37,t1)
     if   s=36  and  int(t1/2)=t1/2  then   line(x,yf)-
(xp(s),yf(s))
     xp(s)=x:if y>0 and y<200 then yp(s)=y:yf(s)=yf
end sub

7100 rem fuel flow display
     cls:screen 2
     locate 1,8:print"Fuel Flow % (100,000scfh)"
     vs=20:vm=25
goto 7005
7200 rem air flow display
     cls:screen 2
     locate 1,8:print"Air Flow %"
     vs=20:vm=25
goto 7005
7300 rem temperature display
     cls:screen 2
     locate 1,8:print"Flue Gas Temp deg C"
     vs=50:vm=75/2:dl=8:ls=20
goto 7005
7400 rem oxygen display
     cls:screen 2
     locate 1,8:print"Oxygen %"
     vs=5:vm=25
goto 7005
7450 rem combustion air temp
     cls:screen 2
     locate 1,8:print"Combustion Air Temp deg C"
     vs=10:vm=200
goto 7005

7500 locate 1,69:lp=len(file$)
     if lp>4 then fle$=mid$(file$,3,lp-5)
     print      dayw$(fdywk);"        ";left$(fle$,2);"-
";mid$(fle$,3,2)
```

```
return

9005        locate       23,75:print"Time":line(41,165)-
(617,165):xp=-3:ls=16
9006 for m=0 to 5
      line(41,5+32*m)-(46,5+32*m): rem 32=160/5
     xp=xp+4:locate xp,1:print vs*(5-m)
next
if wif$<>"" then gosub 9040
if pif$<>"" then gosub 9050
for m=0 to 4:line(41,21+32*m)-(43,21+32*m):next
      bl=165
      gosub 9020
9007 line(41,5)-(41,165)
if choice$="f" then gosub 7500
xp=4
9008  for xn=2 to 24 step 2:nx$=str$(xn):if xn<10  then
nx$=" "+right$(str$(100+xn),2)
      line(41+24*xn,bl-4)-(41+24*xn,bl-2):xp=xp+6
      if s<>otc then locate 22,xp
      if s=otc  then locate 17,xp
      print nx$
next
      for m=1 to 24:line(41+24*m,bl)-(41+24*m,bl-2):next
m
     if choice$="f" then gosub 7500
     if choice$="f" then goto 7020
     dl=9:ls=16:bl=165
goto 7009
9010 rem temperature display
      cls:screen 2:dl=8
      locate 1,8:print"Temperature (C)":vs=10:vm=100
      bl=125:ls=20
      line(41,125)-(617,125)
      gosub 9015
      locate 18,75:print"Time"
goto 9007
9015 gosub 9040
xp=-4
for m=0 to 4
     line(41,5+40*m)-(46,5+40*m)
     xp=xp+5
     locate xp,1
     if s=otc then print vs*(3-m) else print vs*(4-m)
next
      for m=0 to 3:line(41,25+40*m)-(43,25+40*m):next
      gosub 9020
return
9020 if dl=8 then goto 9021
      dl=9
9021 if ls=20 then goto 9022
      ls=16
9022 for m=1 to 24
     for n=1 to dl
     pset(41+24*m,5+ls*n)
     next n
```

```
    next m
return
9040 rem choose channel number s for weather data
if wif$="t" then s=otc
if wif$="r" then s=rhc
if wif$="s" then s=solc
if wif$="w" then s=34
if wif$="d" then s=35
men=6:return

9050 ' choose channel number s for plant data
if pif$="a" then s=36
if pif$="b" then s=38
if pif$="c" then s=42
men=8:return

9100 rem r.h. display
     cls:screen 2
     locate 1,8:print"Relative Humidity %"
     vs=20:vm=100:dl=9:ls=16:bl=165
goto 9005
9200 rem solar display
     cls:screen 2
     locate 1,8:print"Solar Insolation Watts/sq.m"
     vs=200:vm=100000/11.71:dl=9:ls=16:bl=165
goto 9005
9300 rem wind speed display
     cls:screen 2
     locate 1,8:print"Wind Speed mph"
     vs=10:vm=230:dl=9:ls=16:bl=165
goto 9005
9400 rem wind direction display
     cls:screen 2:dl=8
     locate 1,8:print"Wind direction degrees"
     vs=90:vm=100:bl=165:ls=20
     locate 23,75:print"Time":line(41,165)-(617,165)
     xp=-4
  for m=1 to 5:xp=xp+5:locate xp,80
  print dir$(m):next m
     gosub 9015
goto 9007
9500 locate 23,2:lp=len(file$)
     if lp>4 then fle$=mid$(file$,3,lp-5)
     print      dayw$(fdywk);"       ";left$(fle$,2);"-
";mid$(fle$,3,2);"-";yr$
return

pound: rem draw pound sign on screen xst,yst coords  of
top leftof character box:
restore 9610
9600 read co
     if co<>0 then gosub pndplot else return
     goto 9600
9610                                              data
71,60,50,40,31,22,23,24,25,26,16,36,46,56,66,13,33,0
```

```
pndplot:
      x=xst+val(mid$(str$(co),2,1)):y=yst+
val(right$(str$(co),1)):pset(x,y)
return

10000 rem all boilers fuel:
       cls:screen 2
       locate 1,8:print"FUEL Flow (x1000scfh)"
       locate 1,58:print"Ext Temp deg C"
       for n=0 to 4:pset(576+6*n,3):next  n:line(233,3)-
(263,3)
       vs=100:vm=6.25:s=50:bl=165:dl=8:ls=20
goto 11005
10100 rem all boilers cost:
       cls:screen 2
       locate            1,10:print"fuel              COST
/hr":xst=149:yst=0:gosub pound
       locate  2,8:print"flow(1000scf)/hr":for  n=0   to
2:line(193+12*n,11)-(199+12*n,11):next
       locate 1,54:print"ext temp deg C"
       for n=0 to 4:pset(576+6*n,3):next  n:line(193,3)-
(223,3)
      'vs=200:vm=1/8:s=51:bl=165:dl=8:ls=20
goto 11005
10200 rem det max value of r( ) for fuel axis
       fumax=0
       for t=1 to ffr
     gosub 11070
     if f(s,t)>fumax then fumax=f(s,t)
       next t
       if s=50 and fumax<8 then gosub 10210
       if s=50 and fumax<4 then gosub 10220
return
10210 vs=50:vm=12.5:return
10220 vs=25:vm=25:return
10230 rem routines for filed data
       gosub 9500
       if fibo=0 then gosub 12000
       if bap$="o" then return
       if s=51 and cstmax<400 then gosub 10240
       if s=51 and cstmax<200 then gosub 10250
       gosub 10200
return
10240 vs=100:vm=1/4:return
10250 vs=50 :vm=1/2:return
10300 rem all boilers on/off, eff & temp
       cls:screen 2
       locate 1,8: print"Overall efficiency"
       locate 1,58:print"Ext Temp deg C"
       for n=0 to 4:pset(576+6*n,3):next  n:line(233;3)-
(263,3)
       vs=5:vm=125
       bl=165:dl=9:ls=16:s=42:rem    vm    &    s    value
meaningless-included to prev array probs
       for m=0 to 19:line(41,13+8*m)-(43,13+8*m):next
goto 11005
```

```
11005  men=7
if choice$="f" then gosub 10230
rem  locate  23,29:print"A L L     B O I L E R  S":rem
locate 23,75:print"Time"
locate  23,17:print"CENTRAL  SERVICES  AD  BOILERHOUSE
HPHW ENERGY USE"
line(41,5)-(41,165):line(41,165)-(617,165):xp=-4
for n=5 to 165 step 4:pset(617,n):next n
11006  for  m=0 to  4:line(41,5+40*m)-(46,5+40*m):  rem
40=160/4
      line(612,5+40*m)-(617,5+40*m)
      xp=xp+5:locate xp,1
      if bap$="o" then print 90-vs*m else print  vs*(4-
m)
next m
xp=-4
for  m=1  to  4:xp=xp+5:locate   xp,79:vt$=str$((4-
m)*10):lim=len(vt$)
print right$(vt$,lim-1):next m
11007 for m=0 to 3
    if bap$<>"o" then line(41,25+40*m)-(43,25+40*m)
    line(615,25+40*m)-(617,25+40*m)
      next
gosub 9020
xp=4
11008 for xn=2 to 24 step 2:nx$=str$(xn):if xn<10  then
nx$=" "+right$(str$(100+xn),2)
     line(41+24*xn,161)-(41+24*xn,163)
     xp=xp+6:locate 22, xp:print nx$
next
if choice$="f" then goto 11020
11009 fuel=0 :last=lr%
     for t=1 to lr%
     x=35+6*(t+start/15)
     gosub 11060:rem find which boilers on:
     y=165-1.6*vm*r(s,t)
     if s=51 then yf=165-1.6*25*vm*r(50,t):pset(x,yf)
     yt=165-1.6*100*(r(otc,t)-1.12)/1.28:rem   outside
temp scale -10 to 30:
     pset(x,yt)
     yef=165-8*(teff(t)-70)
     if bap$="o" then y=yef
     pset(x,y)
     if  bap$="c"  and  int(t/2)=t/2  then  line(x,yf)-
(xp(s),yf(s))
     if t>1 then line(x,y)-(xp(s),yp(s))
     xp(s)=x:yp(s)=y:yfp(s)=yef:yf(s)=yf
     fuel=fuel+250*calval*r(50,t):rem in therms/hr
     gosub 11400:rem boiler on/off lines
next t
fuel=.25*(fuel-250*calval*(r(50,1)/2+r(50,lr%)/2)):rem
daily fuel
cost=fuel*gaspr
gosub 11350:rem temp data
if          s=51              then              locate
```

```
1,30:print"tot=";int(cost):xst=264:yst=0:gosub
pound:locate 2,30:print"tot=";int(fuel);"th."
if              s=51             then             locate
2,54:print"av";cmeant;"lo";ctmin;"hi";ctmax
if s=50 then locate 1,30:print"tot=";int(fuel);"therm"
11010 if lr%>last then gosub 11050
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
tn$=left$(time$,2)+mid$(time$,4,2):locate
23,2:print"Time ";tn$
goto 11010
11020
fstrt=60*val(left$(fstart$,2))+val(right$(fstart$,2))
      ffuel=0
      for t=1 to ffr
       x=35+6*(t+fstrt/15)
       y=165-1.6*vm*f(s,t)
       if s=51 then yf=165-1.6*25*vm*f(50,t):pset(x,yf)
       yt=165-1.6*100*(f(otc,t)-1.12)/1.28:rem  outside
temp scale -10 to 30:
       pset(x,yt)
       yef=165-8*(fteff(t)-70)
       if bap$="o" then y=yef

       pset(x,y)
       if  bap$="c" and int(t/2)=t/2  then  line(x,yf)-
(xp(s),yf(s))
       if t>1 then line(x,y)-(xp(s),yp(s))
       xp(s)=x:yp(s)=y:yfp(s)=yef:yf(s)=yf
       ffuel=ffuel+250*calval*f(50,t)
      rem if bap$="o" then gosub 11100
      gosub 11100
      next t
ffuel=.25*(ffuel-250*calval*(f(50,1)/2-
f(50,ffr)/2)):rem daily cost
fcost=ffuel*gaspr
if tempcall<>1 then gosub 11300:rem determine ext  temp
data:
if              s=51             then             locate
1,30:print"tot=";int(fcost):xst=264:yst=0:gosub
pound:locate 2,30:print"tot=";int(ffuel);"th."
if              s=51             then             locate
2,54:print"av";meant;"lo";tmin;"hi";tmax
if s=50 then locate 2,58
if s=50 then print"Tot Fuel";int(ffuel);"therm"
if bap$="o" then gosub 11100
fibo=1
idleg:
cs$=inkey$:wn=val(cs$):on wn goto 200,main,300
goto idleg
11050    last=lr%:locate    23,55:rem    print    "Last
reading";last
     tn$=left$(time$,2)+mid$(time$,4,2):locate
23,2:print"Time ";tn$
     x=35+6*(t%+start/15)
     gosub 11065:rem find which boilers on:
     y=165-1.6*vm*r(s,t%)
```

```
      yt=165-1.6*100*(r(otc,t%)-1.12)/1.28:rem   outside
temp scale -10 to 30:
      pset(x,yt)
      yef=165-8*(teff(t%)-70)
      if bap$="o" then y=yef
      pset(x,y)
      line(x,y)-(xp(s),yp(s))
      xp(s)=x:yp(s)=y
      if          t%          >          1          then
fuel=fuel+250*calval*(r(50,t%)+r(50,t%-1))*.25/2
      cost=fuel*gaspr
      gosub 11350:rem temp data
      if           s=51           then            locate
1,30:print"tot=";int(cost):xst=264:yst=0:gosub
pound:locate 2,30:print"tot=";int(fuel);"th."
      if           s=51           then            locate
2,54:print"av";cmeant;"lo";ctmin;"hi";ctmax
      if           s=50           then            locate
1,30:print"tot=";int(fuel);"therm"
      t=lr%:gosub 11400:rem boiler lines
return
11060 rem determine which boilers are on n=boiler no
r(50,t)=0
for n=1 to 5
boil(n)=0
if r(35-6*n,t)<2.4 then boil(n)=1:rem on if oxyg <  15%
i.e.2.4V:
r(50,t)=r(50,t)+boil(n)*r(32-6*n,t)
next n
return
11065 rem determine which boilers are on n=boiler no
r(50,t%)=0
for n=1 to 5
boil(n)=0
if r(35-6*n,t%)<2.4 then boil(n)=1:rem on if oxyg < 15%
i.e.2.4V:
r(50,t%)=r(50,t%)+boil(n)*r(32-6*n,t%)
next n
return

11070 rem determine which boilers are on n=boiler no
f(50,t)=0
for n=1 to 5
boil(n)=0
if f(35-6*n,t)<2.4 then boil(n)=1:rem on if oxyg <  15%
i.e.2.4V:
f(50,t)=f(50,t)+boil(n)*f(32-6*n,t)
next n
return
11100 rem boiler on/off lines
if t>ffr-1 then return
if  bap$<>"c"  then locate  2,8:  print"        boiler
on":line(233,11)-(263,11):line(233,10)-(263,10)
rem   if  bap$="c"  then  locate   3,14:   print"boiler
on":line(193,19)-(223,19):line(193,20)-(223,20)
gosub 11070
```

```
for n=1 to 5
locate 21-n,5:print right$(str$(n),1)
if boil(n)=1 then gosub 11200
next n
return
11200 rem draw lines
for mm=1 to 2:vpp=mm+8*n:vpp=165-vpp
line(41+6*(t-1+fstrt/15),vpp)-(41+6*(t+fstrt/15),vpp)
next mm
return
11300 rem determine ext temp inf for filed data
      if ffr=0 then return
      tmin=50:tmax=0:temptot=0
      for t=1 to ffr
    temp=(f(otc,t)-.8)*100/3.2-20
    if temp>tmax then tmax=temp
    if temp<tmin then tmin=temp
    temptot=temptot+temp
      next t
      meant=temptot/ffr:meant=cint(10*meant)/10    :rem
get rounded mean
      tmax=cint(10*tmax)/10:tmin=cint(10*tmin)/10:rem
round fraction
      tempcall=1
return
11350 rem determine ext temp inf for current data
      if lr%=0 then return
      ctmin=50:ctmax=0:ctemptot=0
      for t=1 to lr%
    temp=(r(otc,t)-.8)*100/3.2-20
    if temp>ctmax then ctmax=temp
    if temp<ctmin then ctmin=temp
    ctemptot=ctemptot+temp
      next t
      cmeant=ctemptot/lr%:cmeant=cint(10*cmeant)/10
:rem get rounded mean
      ctmax=cint(10*ctmax)/10:ctmin=cint(10*ctmin)/10
:rem round fraction
return

11400 rem boiler on/off lines current data
      for n=1 to 5
      locate 21-n,5:print right$(str$(n),1)
      if boil(n)=1 then gosub 11450
      next n
      return
11450 rem draw lines
      if t=1 then return
      for mm=1 to 2:vpp=mm+8*n:vpp=165-vpp
      line(41+6*(t-2+start/15),vpp)-(41+6*(t-
1+start/15),vpp)
      next mm
return

12000 rem calc efficiencies filed data:
fcost=0:cstmax=0
```

```
for t=1 to ffr
enum=0:eden=0
        for n=1 to 5
    oxch=6*n-1
    oxy=f(oxch,t)*25/4
    feff(6-n,t)=0:lod=0
    if oxy>20 then goto 12050 :rem boiler assumed off:
    tfg=f(oxch-1,t)*300/4
    tair=(f(oxch+1,t)-.8)*100/3.2
    delt=tfg-tair
    lod=f(oxch-3,t)/4
    loss=(k1*delt/(20.95-oxy))+k2*(k3+delt)
    if lod>0 then radn=3*.8/lod:rem 3% loss when  lod=.8
(80,000scfh)
    feff(6-n,t)=100-(radn+loss)
12050     enum=enum+feff(6-n,t)*lod
    eden=eden+lod
        next n
        if eden>0 then fteff(t)=enum/eden
        f(51,t)=eden*1000*gaspr*calval:rem total cost per
hr
        if f(51,t)>cstmax then cstmax=f(51,t)
next t
fibo=1
return
```

70% red
draft only